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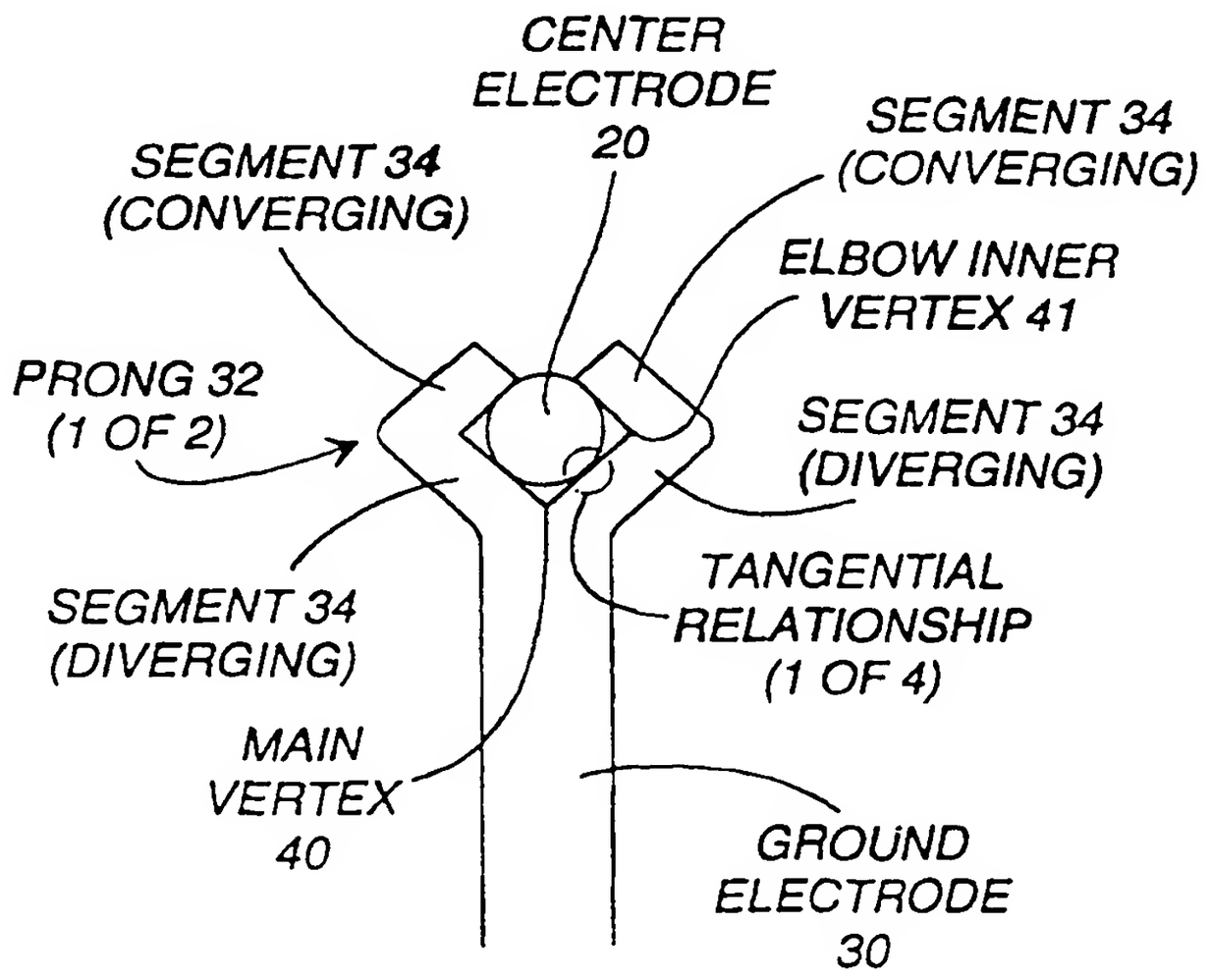
(54) Title: SPARK PLUG PROVIDING IMPROVED OPERATING CHARACTERISTICS

(57) Abstract

The present invention generally relates to spark plugs for igniting the fuel charge in an internal combustion engine, and is particularly concerned with an improved spark plug construction which improves combustion pressure and fuel mileage and diminishes exhaust pollution, as compared with known prior art plugs.



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SPARK PLUG PROVIDING IMPROVED OPERATING CHARACTERISTICS

Reference to Prior Applications

The present invention claims the benefit of and incorporates by reference the following provisional patent applications:

Serial No.60/076,669	Filed March 2, 1998.
Serial No.60/089,458	Filed June 16, 1998.
Serial No.60/089,491	Filed June 16, 1998.
Serial No.60/089,499	Filed June 16, 1998.
Serial No.60/114,439	Filed December 31, 1998.

Technical Field

The present invention generally relates to spark plugs for igniting the fuel charge in an internal combustion engine, and is particularly concerned with an improved spark plug construction which improves combustion pressure, fuel mileage and diminishes exhaust pollution as compared with known prior art plugs.

Background of the Invention

Prior art spark plugs are well known. Such spark plugs typically include a center electrode and a ground electrode spaced apart from the center electrode. When a sufficient electrical potential is provided across the gap, a spark jumps

across the gap. This spark can be used to ignite an air-fuel mixture within an internal combustion engine.

U. S. Patent No. 5,051,651 details a "cylindrical hole" that is created around the center electrode by the shielding of the outer ground electrode. U. S. Patent No. 5,051,651 asserts that "ignition seeds" multiply inside of this cylindrical hole. The ground electrode, in all examples, has a "substantially concave inner surface complimenting the radial face of said center electrode" (Column 8, line 33). This creates a concentric curved surface that has an inner radius equal to "the sum of the radius of the center electrode and a spark gap can be nearly equal to the radius of the cylindrical hole" (Column 1, line 54).

As seen in Figure 13 of Patent 5,051,651, and in the language in independent claim #18, the invention relies specifically on spark strike areas wherein "at least a portion of each said inner orthogonal sides is provided with a concave surface having a curvature complimenting the axial face of the center electrode".

Since all sparks travel along the shortest path, center electrode to ground electrode, the effective surfaces of U. S. Patent No. 5,051,651 are similar to other concentric ring designs (patents #1,748,338; #1,942,242; #1,912,516; #5,430,346; #5,280,214) where the ground electrode is shaped in a complimenting radius centered on the same axis as the center electrode. U. S. Patent No. 5,051.651. at the functional core where the spark actually jumps, performs similarly to other concentric ring designs.

However, it is believed by the applicant that concentric ring designs have shown no performance benefit over standard spark plug designs.

Reference is also made to U. S. Patent No. 5,612,586, in which particular importance is placed upon eliminating the 90 degree bend common to a standard spark plug.

The above prior art patents include some advantageous features. However, there is always a need for an improved plug design which provides improved fuel efficiency and reduced emissions.

Summary of the Invention

The present invention relates to the use of a spark plug providing edge corners in a tangential relationship with the central electrode.

Therefore it is an object of the present invention to provided an improved spark plug.

It is a further object of the present invention to provided an improved spark plug ground electrode.

It is a further object of the present invention to provide an improved spark plug which exhibits improved fuel efficiency.

It is a further object of the present invention to provide an improved spark plug which exhibits improved combustion pressure.

It is a further object of the present invention to provide an improved spark plug which provides decreased pollution.

Other objects, features, and advantages of the present invention will become apparent upon reading the following detailed description of the preferred embodiment of the invention when taken in conjunction with the drawing and the appended claims.

Brief Description of the Drawings

Fig. 1 is a top view of a portion of a first embodiment of the present invention shown in overall view in Fig. 1.

Fig. 2 is a side plan view of the first embodiment shown in Fig. 1, being a spark plug 10.

Fig. 3 is a top view of two electrodes, a ground electrode 51 and a center electrode 20, used in a second embodiment of the present invention, which could be considered a "forked" configuration, with two tangential relationships and one vertex.

Fig. 4 is a top view of two electrodes, a ground electrode 52 and a center electrode 20, used in a third embodiment of the present invention, which includes three segments and three tangential relationships and two vertexes (a.k.a "vertices").

Fig. 5 is a top view of two electrodes, a ground electrode 53 and a center electrode 20, used in a fourth embodiment of the present invention, with six segments, up to five vertexes, and at least four tangential relationships.

Fig. 6 is a top view of two electrodes, a ground electrode 60 and a center electrode 20, used in a fifth embodiment of the present invention, with four segments, three vertexes, and four tangential relationships.

Fig. 7 is a top view of two electrodes, a ground electrode 70 and a center electrode 20, used in a sixth embodiment of the present invention, which could be considered a "closed box" configuration, with four tangential relationships and four vertexes.

Fig. 8 is a top view of two electrodes, a ground electrode 80 and a center electrode 20, used in a seventh embodiment of the present invention, which could be considered a "closed hex box" configuration, with six tangential relationships and six vertexes.

Fig. 9 is a top view of two electrodes, a ground electrode 90 and a center electrode 20, used in a eighth embodiment of the present invention, which could be considered a "single offset straight electrode" configuration, with one tangential relationship.

Fig. 10 is a top view of three electrodes, two ground electrodes 100, 101, and a center electrode 20, used in a ninth

embodiment of the present invention, which could be considered a "double offset straight electrode" configuration, with two tangential relationships.

Fig. 11 is a top view of three electrodes, two ground electrodes 110, 111, and a center electrode 20 used in a tenth embodiment of the present invention, which could be considered a "double T electrode" configuration, with two tangential relationships.

Fig. 12 is a top view of three electrodes, two ground electrodes 120, 121, and a center electrode 20 used in a eleventh embodiment of the present invention, which could be considered an "offset double T electrode" configuration, with two tangential relationships.

Fig. 13 is a top view of four electrodes, three ground electrodes 130, 131, and 132 and a center electrode 20 used in a eleventh embodiment of the present invention, which could be considered a "triangulated triple T electrode" configuration, with three tangential relationships.

Fig. 14 is a side elevational view of a typical center electrode 20, shown underneath a cross-sectional view of a portion of a ground electrode 140, including a lower corner edge directed towards the center electrode in a tangential relationship.

Fig. 15 shows a ground electrode 150 providing a simple convex curved edge presented to the center electrode 20, with one tangential edge relationship. The transverse cross-section of the ground electrode is rectangular.

Fig. 16 shows a simple straight edge presented to the center electrode. One tangential edge relationship is shown. The cross-section of the ground electrode is rectangular.

Fig. 17 shows the use of four ground electrodes 170, 171, 172 and 173, which combine to present multiple simple straight edges presented to the center electrode 20. No tangential edge relationships are shown in this figure, although four edges could be in the zone referenced in Fig. 26. The

cross-section of each of the four ground electrodes is rectangular.

Fig. 18 shows a triangular-shaped ground electrode 180 presenting three edges and three vertexes to the center electrode 20. Three tangential edge relationships are shown. The transverse cross-section of each linear segment of the ground electrode is substantially rectangular.

Fig. 19 is similar to that shown in Fig. 11, and shows a triangular-shaped ground electrode 190, but with a triangular center electrode 195. Three tangential edge relationships and three vertexes are shown in this figure.

Fig. 20 is an open ended design including a ground electrode 200 presenting three curved edges and two vertexes to the center electrode 20. Three "curved" tangential edge relationships are provided under this configuration. Note that a tangential relationship can be a "straight" tangential relationship or can include a "curved" tangential relationship.

Fig. 21 is an open ended design including a ground electrode 210 presenting three straight edges and two vertexes to the center electrode 20. Three tangential edge relationships and two vertexes are shown in this figure.

Fig. 22 is an open ended design similar to that shown in Fig. 21, except with a center electrode 225 shaped substantially matching the ground electrode 220 geometry, which in this case is square. Three tangential relationships are shown.

Fig. 23 shows a "forked" design, in which two curved tangential edge relationships exist, with a single vertex therein. A ground electrode 220 and a center electrode 230 are shown.

Fig. 24 shows two ground electrodes 240, each having a "barb" at their end, which serve to substantially surround the projection of the center electrode 20. Four straight tangential relationships and two vertexes are shown in this figure.

Fig 25 shows a simple concave curved edge presented to the center electrode 20 by a ground electrode 250.

Fig. 26 is a side illustrated view illustrating various positions 1, 2, and 3 that a ground electrode 260 may be placed relative to the center electrode, with these three positions 1, 2 and 3 being within a "zone". The positions within the zone provide such that any of the positions expose the lower edge of the ground electrode to the center electrode's outer edge, which, in the inventor's opinion at the time of filing, can create a "chimney" effect for the intake gases.

Fig. 27 is a side cross-sectional view of the embodiment shown in Fig. 1 (taken through the center longitudinal axis of the center electrode 20) with the lower edges of the ground electrode 270 presented above the center electrode in a substantially tangential relationship to the peripheral projection to the center electrode.

Fig. 28 is a view similar to Fig. 27, but the cross-section of the ground electrode 280 has been streamlined to offer less resistance to the flame front's propagation.

Fig. 29 is a view similar to that of Fig. 28, but the ground electrode 290 has been reduced to a single edge, and supported by an arc, as seen in electrode design shown in Fig. 25. Such a design could also apply to the view of Fig. 15. The cross-section could be of any shape other than that shown, that presents an edge (straight or otherwise) as the closest surface to the top edges of the center electrode 20.

Fig. 30 shows an embodiment including multiple ground electrodes 300, 301, and 302 (a fourth electrode ground, not shown, may also be used) which provides multiple straight edges presented to the center electrode's top via straight angled upwardly and inwardly. The angle is not believed to be as important as the final position of the edges of the tips of the elongate members.

Fig. 31 is a side cross-sectional view of a configuration generally similar to that shown in, for example, Fig. 1, except the cross-section of the ground electrode 310 has a "diamond" shape, presenting edges to the top circular edge of the center

electrode 20. This design could promote better flow for the flame resulting from the spark ignition due to the chamfers above and below the ground electrode edges.

Fig. 32 is a modification of that shown in Fig. 1, except a simple chamfer is provided on the top surface of the ground electrode 320. This could gain some of the benefits of the design shown in Fig. 31, but would appear to be easier to manufacture.

Fig. 33 is a view of an embodiment including a ground electrode which is similar to Fig. 1, except that a simple notch has been cut into the center electrode 335 to improve spark efficiency.

Fig. 34 is a side cross-sectional view of an embodiment similar to that of Fig. 1, including a ground electrode 340, except that a "necked-down" section is provided at the top of the center electrode 345, creating a "fine wire" discharge tip to the center electrode.

Fig. 35 shows a ground electrode 350 edge presented from above, through single (as shown) or multiple (not shown) stems that support the "important" edge Also, the center electrode 355 has a chamfer at the tip.

Fig. 36 shows a configuration which includes "maximized edge-to-edge presentation" of two edges defined by the center and ground electrodes 365, 360, respectively. While possibly more expensive to manufacture than other embodiments, this design presents a less sheilded edge-to-edge spark to the combustion chamber. The small sizes of the electrodes are also believed to serve to reduce blockage to the incoming fule charge and the existing flame kernel.

Fig. 37 is a view of a spark plug having a ground electrode 370 similar to that of Figs. 1 and 2, except that a chisel point center electrode 375 is used.

Fig. 38 is a view of a spark plug having a single point center electrode 385, with a ground electrode 380 being similar to that shown in Figs. 1 and 2.

Fig. 39 is a view of a series of center electrode configurations which may be used with other ground electrodes within this description, including a chisel point 395-A, pyramid point 395-B, a V-groove 395-C, a dimpled center 395-D, a polygon 395-E, a single point 395-F, multiple edges 395-G, a chamfer point 395-H, a hollow cylinder 395-I, a hollow polygon 395-J,and a necked down configuration 395-K.

Fig 40A and B are top and side plan views, respectively, of a configuration including a T-shaped center electrode 405 having T-shaped ends each defining an edge, and a pair of ground electrodes 400, 401 likewise each defining an edge. The edges of the center electrode are presented to the edges of the ground electrodes in a one-to-one relationship.

Figs 41 A and 41 B are top and side plan views, respectively, of a configuration including and L-shaped center electrode 415 and a ground electrode 410, with curved tangential edges. Note that two segments could be used such as in Figs. 40A and 40B, or more than two segments could be used, either with this configuration of the Figs. 40A/40B configuration.

Figs. 42A/42B show a configuration which includes a center electrode 425 and a ground electrode 420, combining to form three tangential relationships.

Fig. 43 is a configuration which includes a center electrode 20 and a ground electrode 430, which provides vertical and horizontal spacing between the two referenced as G1 and G2, respectively. Preferably G1 is greater than or equal to zero and G2 is greater than or equal to zero. This is another way to illustrate the "zone" concept of Fig. 26.

Fig. 44 is an illustrative top plan view of an exemplary center electrode 20 and two exemplary ground electrodes 440, 441, further illustrating the tangential relationship which is one feature of the present invention. As may be seen, a "tangential" relationship includes not only the "case 1"

relationship of the elements 20, 440, but also the "case 2" relationship of the elements 20, 441.

Fig. 45 is an illustrative top plan view of an exemplary center electrode 20 and a two-pronged ground electrode 450, which is similar to that shown in Fig. 3 but has shorter prongs which provide two tangential relationships 453, 454, as shown in the case 2 example in Fig. 44. An intermediate vertex 455 is also shown.

Fig. 46 is a "wide-box" configuration which is similar to that of Fig. 1, except that instead of having four tangential relationships, the four edges of the ground electrode 460 are outside the projection of the center electrode, and in the "zone" of Fig. 26. In the inventor's opinion at the time of filing, this provides additional room under the "intake charge flow" concept illustrated in Fig. 26.

Fig. 47 is a "wide-fork" configuration which is similar to that of Fig. 3, except that instead of having two tangential relationships, the two edges of the ground electrode 470 are outside the projection of the exemplary center electrode 20, and in the "zone" of Fig. 26. In the inventor's opinion at the time of filing, this provides additional room under the "intake charge flow" concept illustrated in Fig. 26.

Fig. 48 illustrates a believed difference in concentric and nonconcentric electrode properties, showing a concentric ground electrode 480, an "open" ground electrode 481, each in association with a typical center electrode 20. As may be seen, open electrode surfaces are believed by the inventor to tend to encourage flame kernel propagation.

Detailed Description of the Preferred Embodiment

Generally described, the present invention is directed towards the use of a spark plug having a conventional center electrode and one or more ground electrodes, each of which defines at least one lower corner edge which is substantially

tangentially oriented relative to the periphery of the substantially round electrode below.

One configuration contemplated under the present invention can be referred to as a "box" plug, shown in Figs. 1 and 2. The "box" plug uses an electrode that is substantially in the shape of a square that appears to "encircle" the spark plug's center electrode, when viewed from above. However, in fact, as shown in Fig. 2, the box does not encircle the spark plug's center electrode, as there is a gap (0.025" in the case of one test) defined between the upper round end surface of the center electrode and the plane in which the downwardly-directed lower surfaces of the split prong members lie.

As may be seen, the electrode 30 includes two end prongs 32 which initially diverge but then eventually converge. The two end prongs 32 each include two segments 34 of substantially equal length. Two of these segments could be considered as the "diverging" segments 34, and the other two could be considered as the "converging" segments 34. This would mean that each prong includes one "diverging" segment and one "converging" segment.

An "Elbow" could be considered as connecting the diverging segment of a particular segment to its corresponding converging segment. Such elbows (two in the Fig. 1 version) are shown as being substantially in a vertical plane extending through the central longitudinal axis of the center prong.

The ground electrode could be considered to have three vertexes, a main vertex 40 and two elbow inner vertexes 41

It may be understood that the transverse cross sections of the segments 34 are substantially rectangular, being in one configuration 0.050" wide and 0.050" thick. Such a cross section provides four outwardly-directed, substantially linear (at least not near the bends) corner edges, (also shown in Fig. 14). It is believe that the relationship of at least the inner lower corner edges relative to the center electrode provides improved performance. Such a relationship will be referred

to as a tangential relationship, with four tangential relationships provided in the Fig. 1 configuration, one for each segment 34.

It should be understood that the center electrode as shown in Fig. 2 shall be referenced in this application as an "upwardly"-extending center electrode. However, this is for reference purposes only and should not be understood as limiting. In operation such an electrode can be oriented in many difference directions while in use.

Other Embodiments

Other ground electrode embodiments are contemplated under the present invention.

Fig. 3 is a top view of two electrodes, a ground electrode 51 and a center electrode 20, used in a second embodiment of the present invention, which could be considered a "forked" configuration, with two tangential relationships and one vertex.

Fig. 4 is a top view of two electrodes, a ground electrode 52 and a center electrode 20, used in a third embodiment of the present invention, which includes three segments and three tangential relationships and two vertexes (a.k.a "vertices").

Fig. 5 is a top view of two electrodes, a ground electrode 53 and a center electrode 20, used in a fourth embodiment of the present invention, with six segments, up to five vertexes, and at least four tangential relationships.

Fig. 6 is a top view of two electrodes. a ground electrode 60 and a center electrode 20, used in a fifth embodiment of the present invention, with four segments, three vertexes, and four tangential relationships.

Fig. 7 is a top view of two electrodes. a ground electrode 70 and a center electrode 20, used in a sixth embodiment of the present invention. which could be

considered a "closed box" configuration, with four tangential relationships and four vertexes.

Fig. 8 is a top view of two electrodes, a ground electrode 80 and a center electrode 20, used in a seventh embodiment of the present invention, which could be considered a "closed hex box" configuration, with six tangential relationships and six vertexes.

Fig. 9 is a top view of two electrodes, a ground electrode 90 and a center electrode 20, used in a eighth embodiment of the present invention, which could be considered a "single offset straight electrode" configuration, with one tangential relationship.

Fig. 10 is a top view of three electrodes, two ground electrodes 100, 101, and a center electrode 20, used in a ninth embodiment of the present invention, which could be considered a "double offset straight electrode" configuration, with two tangential relationships.

Fig. 11 is a top view of three electrodes, two ground electrodes 110, 111, and a center electrode 20 used in a tenth embodiment of the present invention, which could be considered a "double T electrode" configuration. with two tangential relationships.

Fig. 12 is a top view of three electrodes, two ground electrodes 120, 121, and a center electrode 20 used in a eleventh embodiment of the present invention, which could be considered an "offset double T electrode" configuration, with two tangential relationships.

Fig. 13 is a top view of four electrodes, three ground electrodes 130, 131, and 132 and a center electrode 20 used in a eleventh embodiment of the present invention. which could be considered a "triangulated triple T electrode" configuration, with three tangential relationships.

Fig. 14 is a side elevational view of a typical center electrode 20, shown underneath a cross-sectional view of a portion of a ground electrode 140. including a lower corner

edge directed towards the center electrode in a tangential relationship.

Fig. 15 shows a ground electrode 150 providing a simple convex curved edge presented to the center electrode 20, with one tangential edge relationship. The transverse cross-section of the ground electrode is rectangular.

Fig. 16 shows a simple straight edge presented to the center electrode. One tangential edge relationship is shown. The cross-section of the ground electrode is rectangular.

Fig. 17 shows the use of four ground electrodes 170, 171, 172 and 173, which combine to present multiple simple straight edges presented to the center electrode 20. No tangential edge relationships are shown in this figure. The cross-section of each of the four ground electrodes is rectangular.

Fig. 18 shows a triangular-shaped ground electrode 180 presenting three edges and three vertexes to the center electrode 20. Three tangential edge relationships are shown. The transverse cross-section of each linear segment of the ground electrode is substantially rectangular.

Fig. 19 is similar to that shown in Fig. 11, and shows a triangular-shaped ground electrode 190, but with a triangular center electrode 195. Three tangential edge relationships and three vertexes are shown in this figure.

Fig. 20 is an open ended design including a ground electrode 200 presenting three curved edges and two vertexes to the center electrode 20. Three "curved" tangential edge relationships are provided under this configuration. Note that a tangential relationship can be a "straight" tangential relationship or can include a "curved" tangential relationship.

Fig. 21 is an open ended design including a ground electrode 210 presenting three straight edges and two vertexes to the center electrode 20. Three tangential edge relationships and two vertexes are shown in this figure.

Fig. 22 is an open ended design similar to that shown in Fig. 21, except with a center electrode 225 shaped substantially matching the ground electrode 220 geometry, which in this case is square. Three tangential relationships are shown.

Fig. 23 shows a "forked" design, in which two curved tangential edge relationships exist, with a single vertex therein. A ground electrode 220 and a center electrode 230 are shown.

Fig. 24 shows two ground electrodes 240, each having a "barb" at their end, which serve to substantially surround the projection of the center electrode 20. Four straight tangential relationships and three vertexes are shown in this figure.

Fig 25 shows a simple curved edge presented to the center electrode 20 by a ground electrode 250.

Fig. 26 is a side illustrated view illustrating various positions 1, 2, and 3 that a ground electrode 260 may be placed relative to the center electrode, with these three positions 1, 2 and 3 being within a "zone". The positions within the zone provide such that any of the positions expose the lower edge of the ground electrode to the center electrode's outer edge, which, in the inventor's opinion at the time of filing, can create a "chimney" effect for the intake gases.

Fig. 27 is a side cross-sectional view of the embodiment shown in Fig. 1 (taken through the center longitudinal axis of the center electrode 20) with the lower edges of the ground electrode 270 presented above the center electrode in a substantially tangential relationship to the peripheral projection to the center electrode.

Fig. 28 is a view similar to Fig. 27, but the cross-section of the ground electrode 280 has been streamlined to offer less resistance to the flame front's propagation.

Fig. 29 is a view similar to that of Fig. 28, but the ground electrode 290 has been reduced to a single edge, and supported by an arc, as seen in electrode design shown in Fig. 25. Such a design could also apply to the view of Fig. 15. The cross-section could be of any shape other than that shown, that

presents an edge (straight or otherwise) as the closest surface to the top edges of the center electrode 20.

Fig. 30 shows an embodiment including multiple ground electrodes 300, 301, and 302 (a fourth electrode ground, not shown, may also be used) which provides multiple straight edges presented to the center electrode's top via straight angled upwardly and inwardly. The angle is not believed to be as important as the final position of the edges of the tips of the elongate members.

Fig. 31 is a side cross-sectional view of a configuration generally similar to that shown in, for example, Fig. 1. except the cross-section of the ground electrode 310 has a "diamond" shape, presenting edges to the top circular edge of the center electrode 20. This design could promote better flow for the flame resulting from the spark ignition due to the chamfers above and below the ground electrode edges.

Fig. 32 is a modification of that shown in Fig. 1. except a simple chamfer is provided on the top surface of the ground electrode 320. This could gain some of the benefits of the design shown in Fig. 31. but would appear to be easier to manufacture.

Fig. 33 is a view of an embodiment including a ground electrode which is similar to Fig. 1, except that a simple notch has been cut into the center electrode 335 to improve spark efficiency.

Fig. 34 is a side cross-sectional view of an embodiment similar to that of Fig. 1. including a ground electrode 340, except that a "necked-down" section is provided at the top of the center electrode 345. creating a "fine wire" discharge tip to the center electrode.

Fig. 35 shows a ground electrode 350 edge presented from above, through single (as shown) or multiple (not shown) stems that support the "important" edge Also. the center electrode 355 has a chamfer at the tip.

Fig. 36 shows a configuration which includes "maximized edge-to-edge presentation" of two edges defined by the center and ground electrodes 365, 360, respectively. While possibly more expensive to manufacture than other embodiments, this design presents a less shielded edge-to-edge spark to the combustion chamber. The small sizes of the electrodes are also believed to serve to reduce blockage to the incoming fuel charge and the existing flame kernel.

Fig. 37 is a view of a spark plug having a ground electrode 370 similar to that of Figs. 1 and 2, except that a chisel point center electrode 375 is used.

Fig. 38 is a view of a spark plug having a single point center electrode 385, with a ground electrode 380 being similar to that shown in Figs. 1 and 2.

Fig. 39 is a view of a series of center electrode configurations which may be used with other ground electrodes within this description, including a chisel point 395-A, pyramid point 395-B, a V-groove 395-C, a dimpled center 395-D, a polygon 395-E, a single point 395-F, multiple edges 395-G, a chamfer point 395-H, a hollow cylinder 395-I, a hollow polygon 395-J,and a necked down configuration 395-K.

Fig 40A and B are top and side plan views, respectively, of a configuration including a T-shaped center electrode 405 having T-shaped ends each defining an edge, and a pair of ground electrodes 400, 401 likewise each defining an edge. The edges of the center electrode are presented to the edges of the ground electrodes in a one-to-one relationship.

Figs 41 A and 41 B are top and side plan views, respectively, of a configuration including and L-shaped center electrode 415 and a ground electrode 410, with curved tangential edges. Note that two segments could be used such as in Figs. 40A and 40B, or more than two segments could be used, either with this configuration of the Figs. 40A/40B configuration.

Figs. 42A/42B show a configuration which includes a center electrode 425 and a ground electrode 420, combining to form three tangential relationships.

Fig. 43 is a configuration which includes a center electrode 20 and a ground electrode 430, which provides vertical and horizontal spacing between the two referenced as G1 and G2, respectively. Preferably G1 is greater than or equal to zero and G2 is greater than or equal to zero. This is another way to illustrate the "zone" concept of Fig. 26.

Fig. 44 is an illustrative top plan view of an exemplary center electrode 20 and two exemplary ground electrodes 440, 441, further illustrating the tangential relationship which is one feature of the present invention. As may be seen, a "tangential" relationship includes not only the "case 1" relationship of the elements 20, 440, but also the "case 2" relationship of the elements 20, 441.

Fig. 45 is an illustrative top plan view of an exemplary center electrode 20 and a two-pronged ground electrode 450, which is similar to that shown in Fig. 3 but has shorter prongs which provide two tangential relationships 453, 454, as shown in the case 2 example in Fig. 44. An intermediate vertex 455 is also shown.

Fig. 46 is a "wide-box" configuration which is similar to that of Fig. 1, except that instead of having four tangential relationships, the four edges of the ground electrode 460 are outside the projection of the center electrode, and in the "zone" of Fig. 26.

Fig. 47 is a "wide-fork" configuration which is similar to that of Fig. 3, except that instead of having two tangential relationships, the two edges of the ground electrode 470 are outside the projection of the exemplary center electrode 20, and in the "zone" of Fig. 26. In the inventor's opinion at the time of filing, this provides additional room under the "intake charge flow" concept illustrated in Fig. 26.

The Tangential Relationship

As noted above, in some instances it is desired to have a one or more straight edges in a tangential relationship with the circular (a.k.a "round") upper edge of the ground electrode. This will be referred to as a "straight edge tangential relationship" in that the straight edge defined by the ground electrode presents one or more straight edges such that each edge is in a tangential relationship to the center electrode's circumferential projection. Such is shown in, for example only, Figs. 1, 3, 4, 9, and 10, although many others are shown).

However, it should also be understood that a "curved edge tangential relationship is also contemplated under one of the inventions disclosed herein, which is shown in, for example only, Figs. 15, 23, and 25.

The important point to note is that the spark will connect between the center electrode and the closest ground. The actual placement of the ground electrode's prongs may be anywhere adjacent to or outside the peripheral (which need not necessarily be round) projection of the center electrode, at a chosen height at or above the center electrode's tip.

It should be understood that certain aspects of the invention contemplate the use of some offset of the tangential relationship, such as shown in Figs 17 and 26.

The Straightness of the Edges

As noted above, in some instances it is desired to have a straight edge in a tangential relationship with the curved upper edge of the ground electrode. However, it should be understood that certain aspects of the invention contemplate the use of curved edges in such a tangential relationship.

The Zone Concept

Reference is made to Figs. 26 to illustrate the "Zone" concept, in which any of the positions shown expose the lower

edge of the ground electrode to the center electrode's outer edge (a.k.a. its "upper peripheral edge", which could be circular).

This is another related concept of the related invention, in which the edges which are presented or exposed to each other are not necessarily tangential, but they do present themselves to each other such that the edges are the closest parts of the two electrodes to each other, or are at least as close as any other two parts of the electrodes, within the region of spark. It is believed at the time of filing that the "unshielding" of the top of the center electrode by placing the ground electrode outside the periphery is an advantageous concept above and separate from the tangential and-or vertex concepts. Again it is believed that placing the lowest portion of the ground electrode's "active edge" at or above the center electrode allows the intake charge gases to flow more easily into the spark zone.

The Vertexes

It is believed at the time of filing that the combination of the tangential relationship and the vertexes. which is provided in some of the applicant's embodiments (for example those shown in Figs. 1, 3, 4, 5, 6, and others) provides a distinct improvement over the prior art. Some of such vertexes provide a vertical "opening" or a "chimney effect" which is believed to provide improved flame characteristics. Furthermore, it is believed at the time of filing that the combination of the "zone" relationship and the vertexes, which is provided in some of the applicant's embodiments, provides a distinct improvement over the prior art

Processes Used

The simple shapes of the ground electrodes described in this application can be created by a secondary and subsequent operations on the standard wire-fed electrode currently in use

in the industry. A mandrel of specific design can be used to form the various segments of each electrode. Alternately, a stamped electrode can be made using a die to create the specific configuration. The stamped electrode could then be welded to the spark plug base per usual practice. Instead of stamping, the electrode shape could be created by laser cutting, water jet cutting, chemical etching, forging, casting, powdered metal forming, etc. Any electrodes using these methods would then be welded to the spark plug base at the appropriate position.

With respect to the configurations shown in Figures 9 and 10, these electrode configurations can be created with little change to the current wire-feed arrangement. The offset with respect to the center electrode can be created in the basic wire feed machine set up, or by the use of a secondary operation that creates the specific alignment of the conventional sidewire.

Miscellaneous Comments

In, for example, Fig. 1, the thickness of the ground electrodes, including the end portions (including their segments), is as known in the art, or approximately 0.050", although the thickness can be 0.040 – 0.065", although it could be 0.010"- 0.150", or other dimensions without departing from the spirit and scope of the present invention. The width of the "stem" can be 0.075 – 0.125" , although it could be 0.010"- 0.150", or other dimensions without departing from the spirit and scope of the present invention.

It is believed that the width of the prongs is not critical, but the sharpness of the edge(s) is important. However, in one preferred embodiment, the prongs are 0.050" wide and 0.050" thick, although each of these dimensions could be 0.010"-0.150", or other dimensions without departing from the spirit and scope of the present invention.

It should also be understood that it is not believed that the ground electrode be square or rectangular, as long as it

includes a sharp corner which presents the lower corner edge to the center electrode as shown in Fig. 14 or 26.

The center electrode diameter can be 0.010"- 0.150". The thickness of the electrode "stem", where applicable, can be 0.040 – 0.065" , although it could be 0.010"- 0.150", or other dimensions without departing from the spirit and scope of the present invention.

The materials used throughout are such as known in the art, including presently-used "premium" materials (e.g., platinum).

Comparison to the Prior Art

In contrast to U. S. Patent No. 5,051,651, in the present invention, the striking surface for the spark on the ground electrode has been shaped in an open concave curve, a straight line, or even a convex curve in order to clear the way for the flame kernel to expand away from the sparking point. This occurs at a microscopic level such that any hint of a concentric radius on the striking surface has a negative effect on flame kernel growth. This discovery of the extreme sensitivity of the combustion process to this striking surface radius is one important part of one of our inventions.

It is believed that concentric ring designs, no mater how minimal the length of the concentrically curved section is, perform no better in practice than conventional spark plug designs. This is the substantial difference between the Pyrotek invention and the one described in patent #5,051,651. The latter always relies on a "hollow cylindrical ground electrode...by which combustion gas can gush out from..." (Column 2, line 59).

The ground electrode spacing in Patent #5,051,651 is always spaced away from the center electrode by a gap. In the Pyrotek invention, tangential relationships are useful due to the open nature of the striking surface. Any concentric radius

imparted to the striking surface in a tangential relationship would severely constrain the flame kernel generation.

Finally, Patent #5,051,651 incorporates two mounting stems which have a certain amount of shielding effect on the flame kernel, particularly when compared to the single stem of the preferred embodiment of the Pyrotek invention.

Conclusion

While this invention has been described in specific detail with reference to the disclosed embodiments, it will be understood that many variations and modifications may be effected within the spirit and scope of the invention as described in the appended claims.

CLAIMS

What is claimed is:

1. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

an upwardly-extending center electrode having a cross-sectional projection and a height; and

a ground electrode defining an elongate edge longer than the major dimension of the center electrode, said elongate edge at a substantially tangential relationship relative to said cross-sectional projection of said upwardly-extending center electrode, said elongate edge of said ground electrode having its lowest portion at or higher than the highest portion of said center electrode.

2. The spark plug of Claim 1, wherein said edge is substantially straight.

3. The spark plug of Claim 1, wherein said edge lies along a curved path having a radius greater than said center electrode and having a center of radius dissimilar than that of said center electrode.

4. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

an upwardly-extending center electrode defining a center electrode edge; and

a ground electrode defining an elongate ground electrode edge longer than the major dimension of the center electrode,

said elongate ground electrode edge spaced apart from said center electrode edge,

said elongate ground electrode edge at or above said center electrode edge,

said elongate ground electrode edge at or outside said center electrode edge,

such that said center electrode edge and said elongate ground electrode edge are presented towards each other such that they are or are among the closest portions of their two respective electrodes within the sparking region.

5. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

an upwardly-extending center electrode defining a center electrode edge; and

a ground electrode defining an elongate ground electrode edge,

said elongate ground electrode edge spaced apart from said center electrode edge,

said elongate ground electrode edge at or above said center electrode edge,

said elongate ground electrode edge at or outside said center electrode edge,

said elongate ground electrode edge and said center electrode edge having portions being nonconcentric,

such that said center electrode edge and said elongate ground electrode edge are presented towards each other such that they are or are among the closest portions of their two respective electrodes within the sparking region.

6. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

an upwardly-extending center electrode having a cross-sectional projection and a height; and

a ground electrode defining an elongate edge longer than the major dimension of the center electrode, said edge being outside the projection and having its lowest portion at or higher than the highest portion of said center electrode.

7. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

an upwardly-extending center electrode having a substantially circular transverse cross-section having a diameter; and

a ground electrode defining an elongate edge at least at long as said diameter and spaced above and outside said projection and having its lowest portion at or higher than the highest portion of said center electrode.

8. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

an upwardly-extending center electrode having a cross-sectional projection; and

a ground electrode defining two elongate edges each in a substantially tangential relationship relative to said cross-sectional projection of said upwardly-extending center electrode, said edges also combining to form one intermediate vertex outside said projection.

9. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

an upwardly-extending center electrode having a cross-sectional projection; and

a box-shaped ground electrode with a split at the end with each end turned back, providing four tangential relationships relative to the cross-sectional projection and also providing three intermediate vertexes.

10. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

an upwardly-extending center electrode defining an elongate edge; and

a ground electrode defining an edge,

said center electrode edge and said ground electrode edge being in a non-concentric relationship and oriented towards each other to allow for sparking therebetween.

11. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

a center electrode; and

a ground electrode including a main portion extending to above the center electrode and diverging into two prongs, said prongs forming a partial "box" shape, said box shape including four sections oriented substantially tangential to said circular outline of said ground electrode.

12. The spark plug as claimed in Claim 11, wherein said spark electrode includes a vertex portion located outside of the periphery.

13. The spark plug as claimed in Claim 12, such that at least two (of four) segments of the two prongs lie substantially along said periphery.

14. The spark plug as claimed in Claim 13, such that first and third portions are substantially parallel.

15. The spark plug as claimed in Claim 14, such that said second and fourth sections are substantially parallel.

16. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

a center electrode; and

a ground electrode extending to above the center electrode, said ground electrode defining at least three tangential relationships.

17. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

a center electrode; and

a ground electrode extending to above the center electrode, said ground electrode defining at least four tangential relationships.

18. A spark plug for providing a spark within a sparking region, said spark plug when in an upright position comprising:

a center electrode; and

a ground electrode extending to above the center electrode, said ground electrode defining at least five tangential relationships.

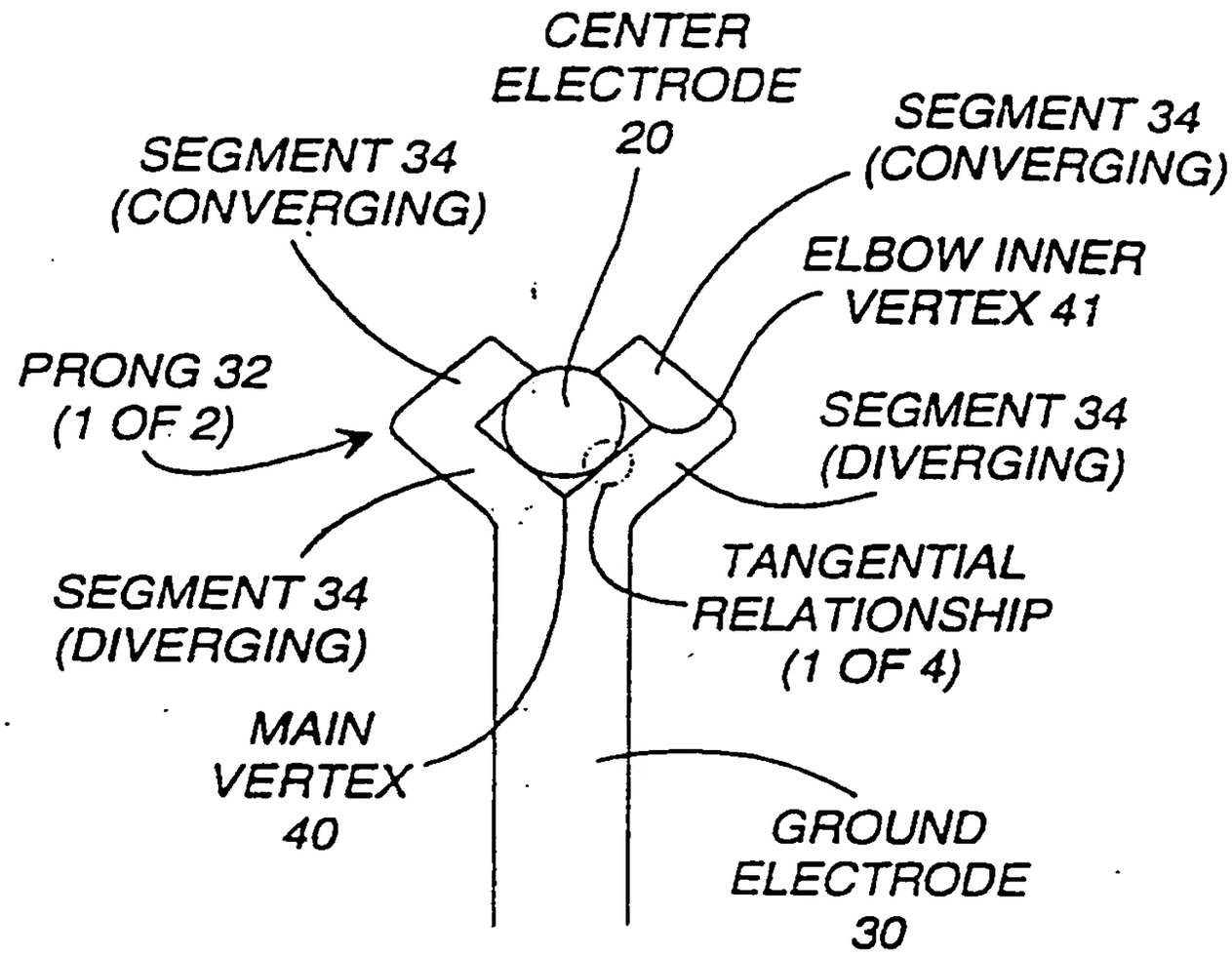


FIG. 1

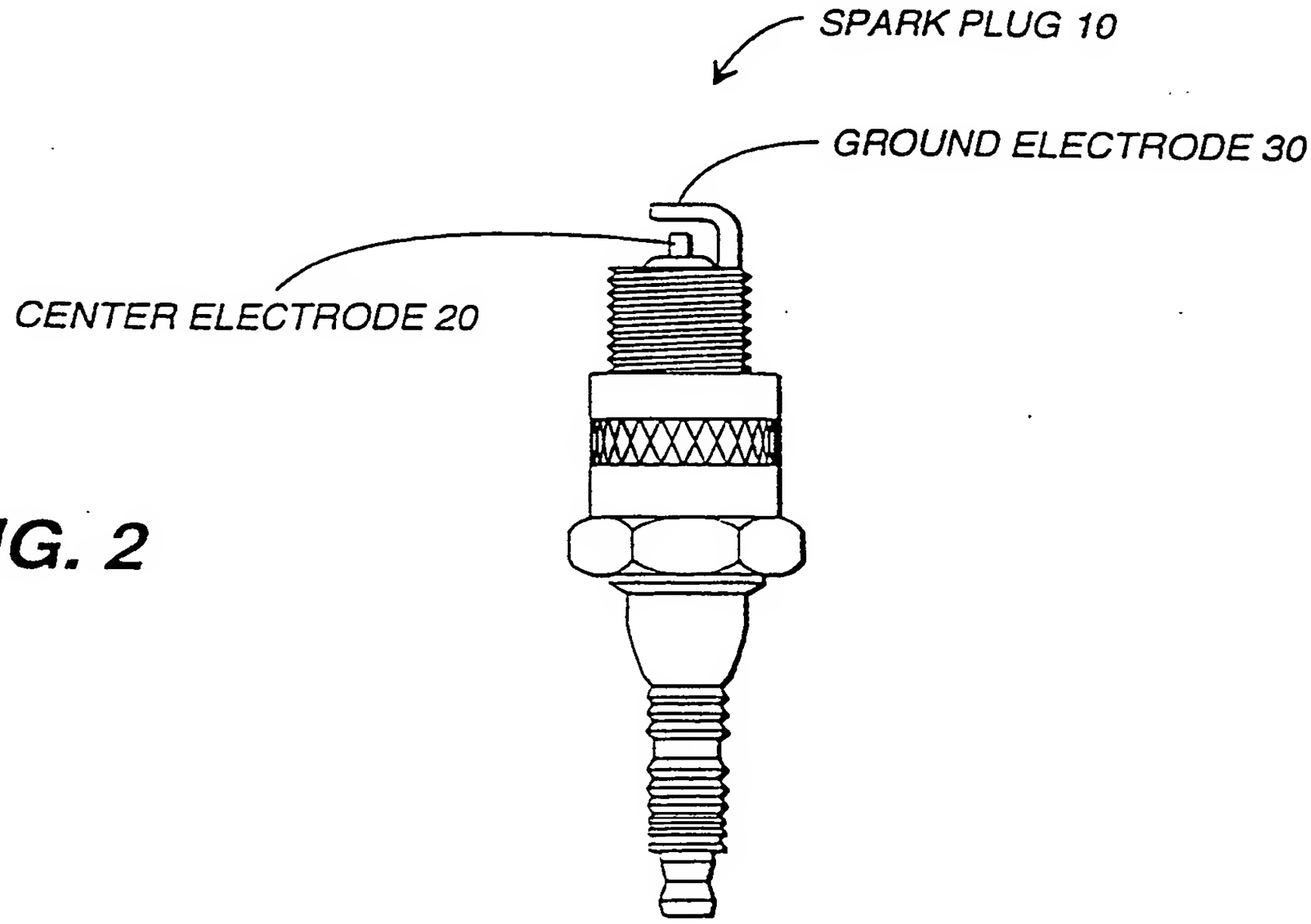


FIG. 2

FIG. 3

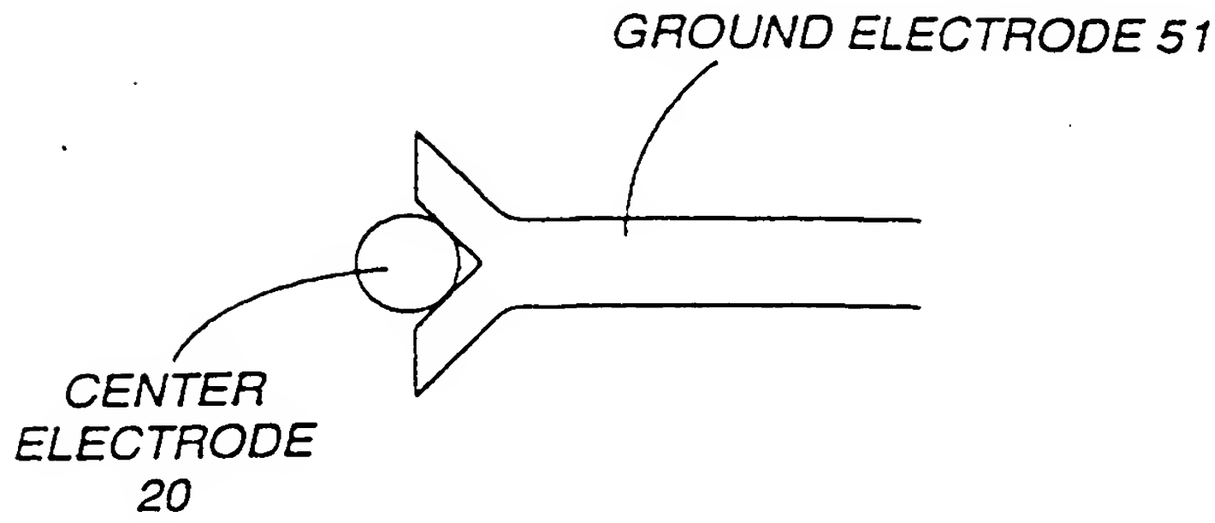


FIG. 4

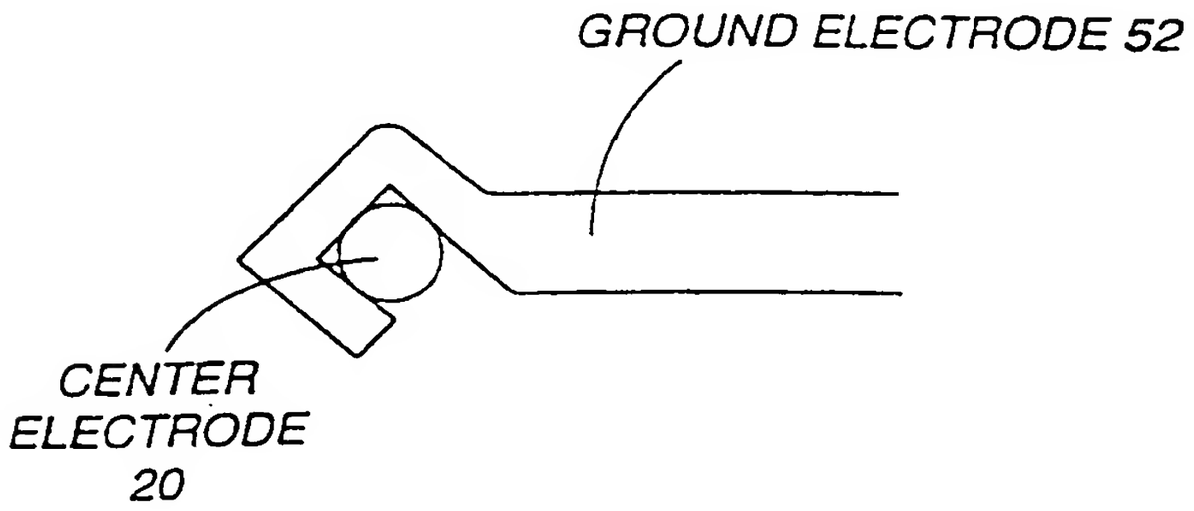


FIG. 5

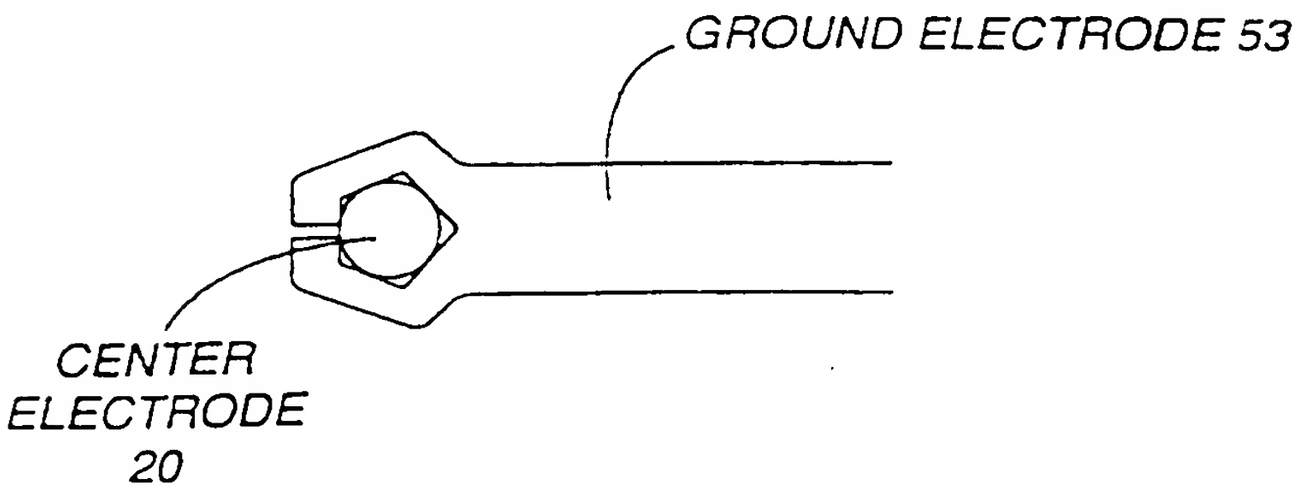
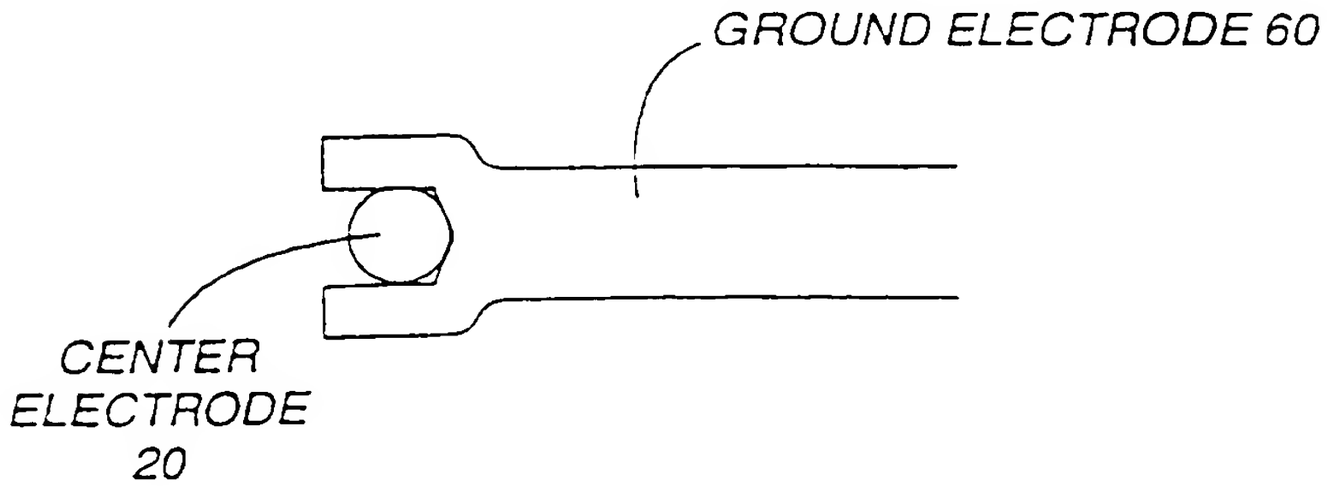


FIG. 6



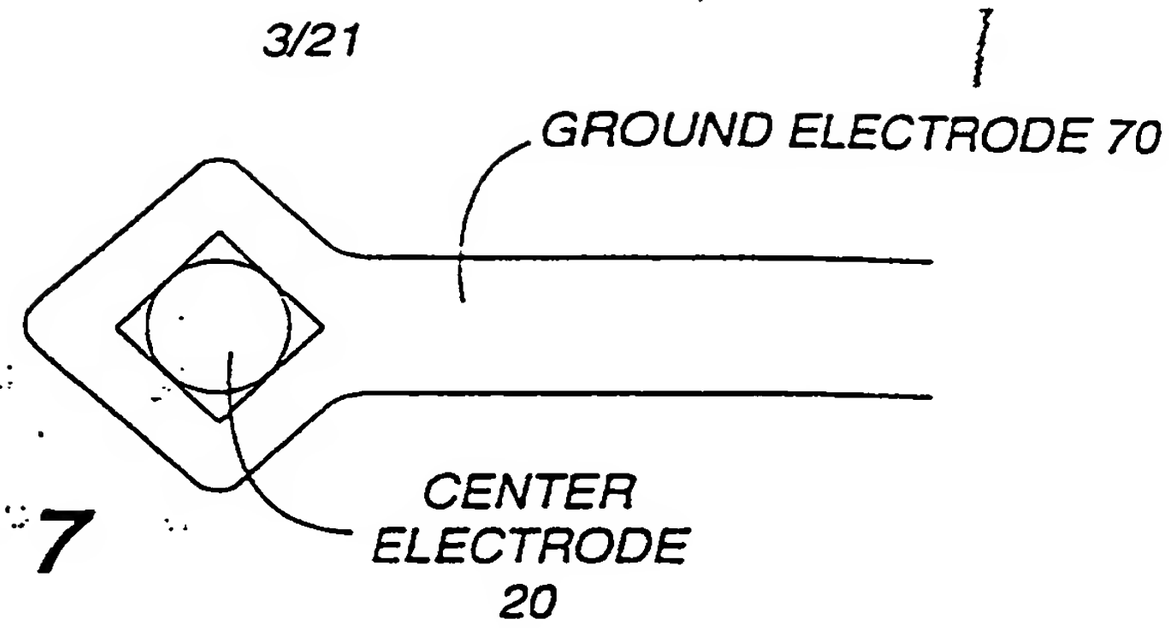


FIG. 7

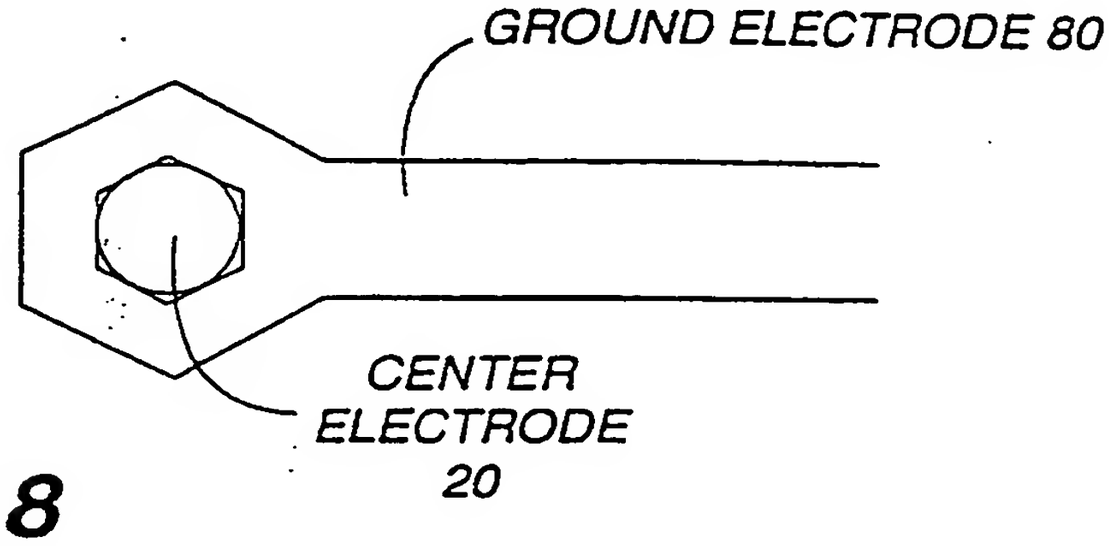


FIG. 8

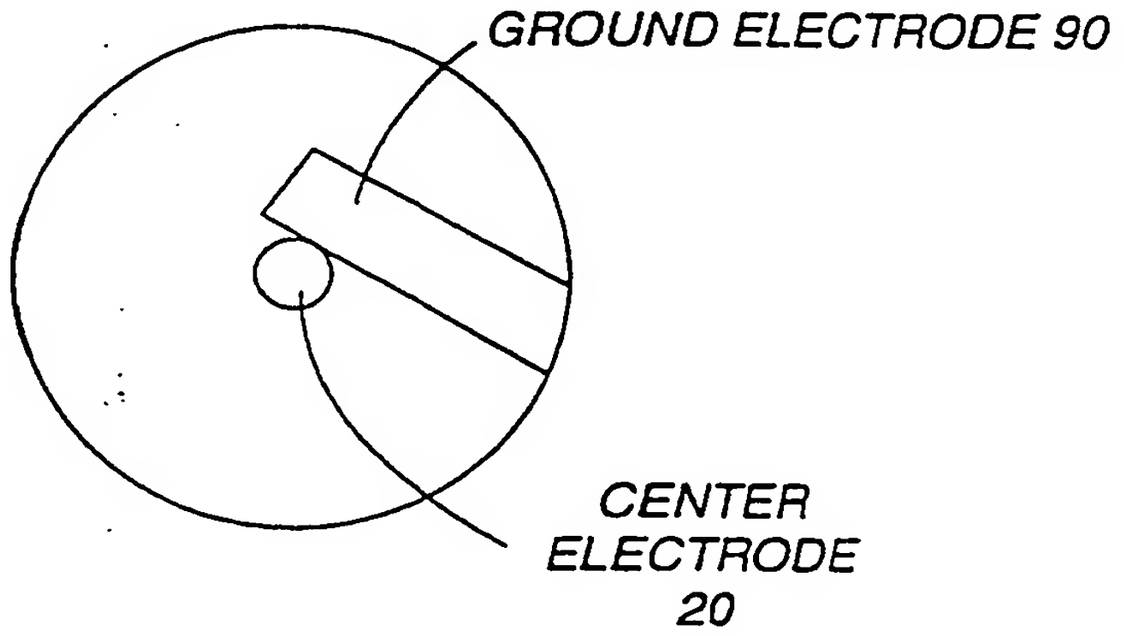


FIG. 9

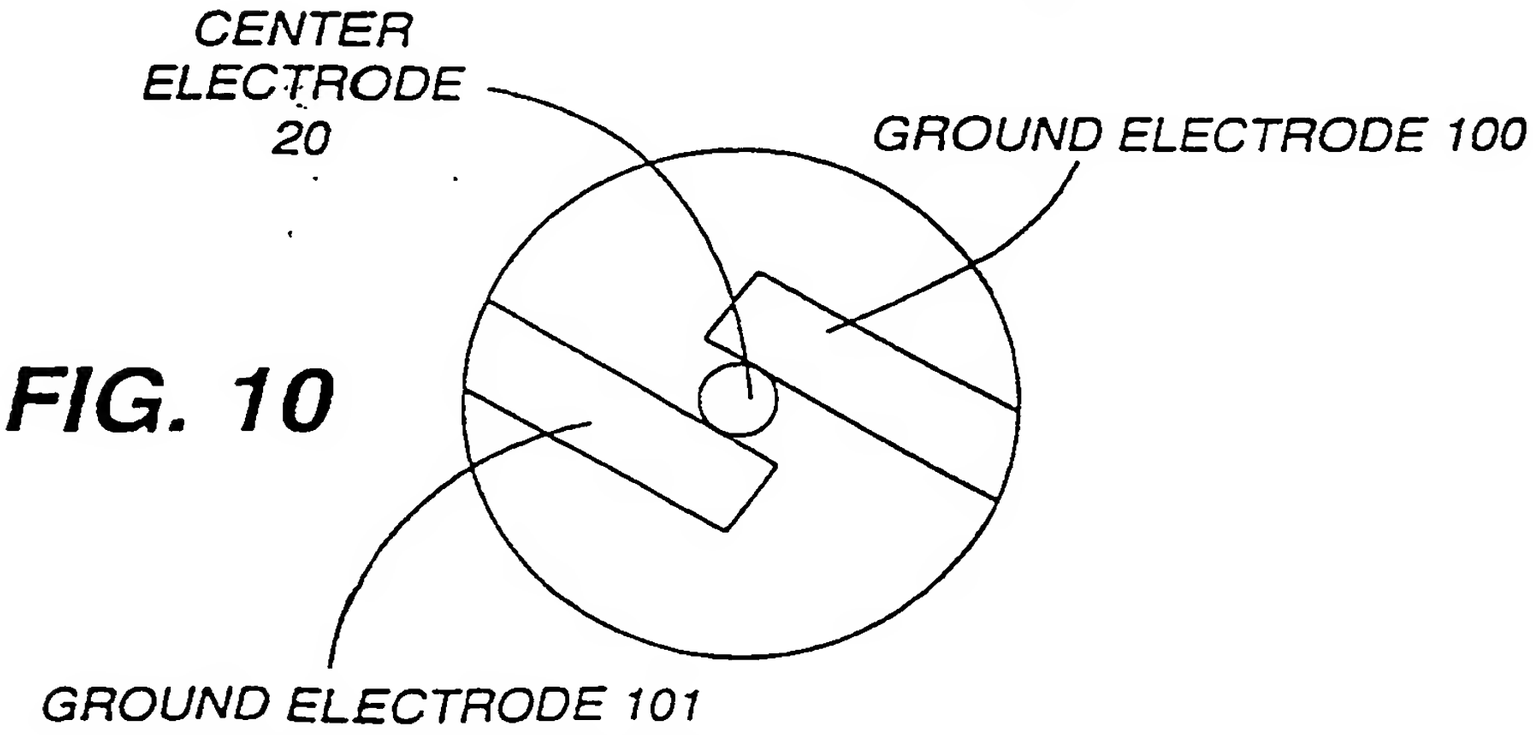


FIG. 10

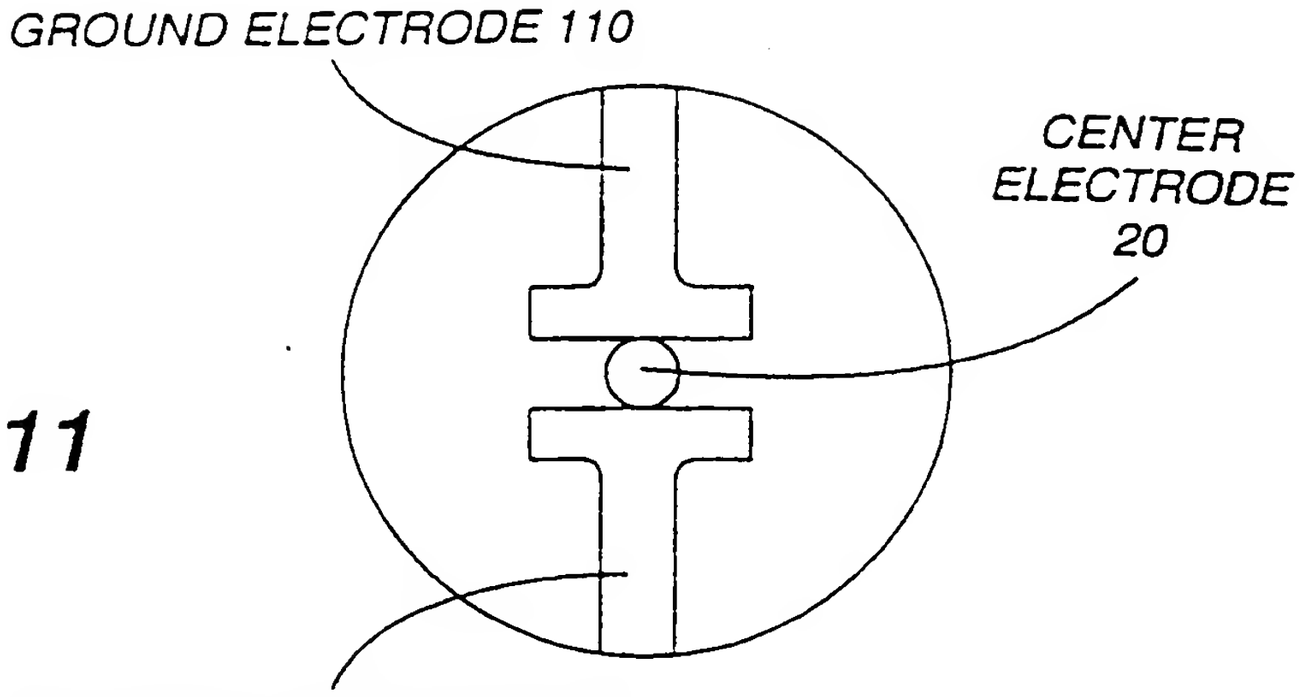


FIG. 11

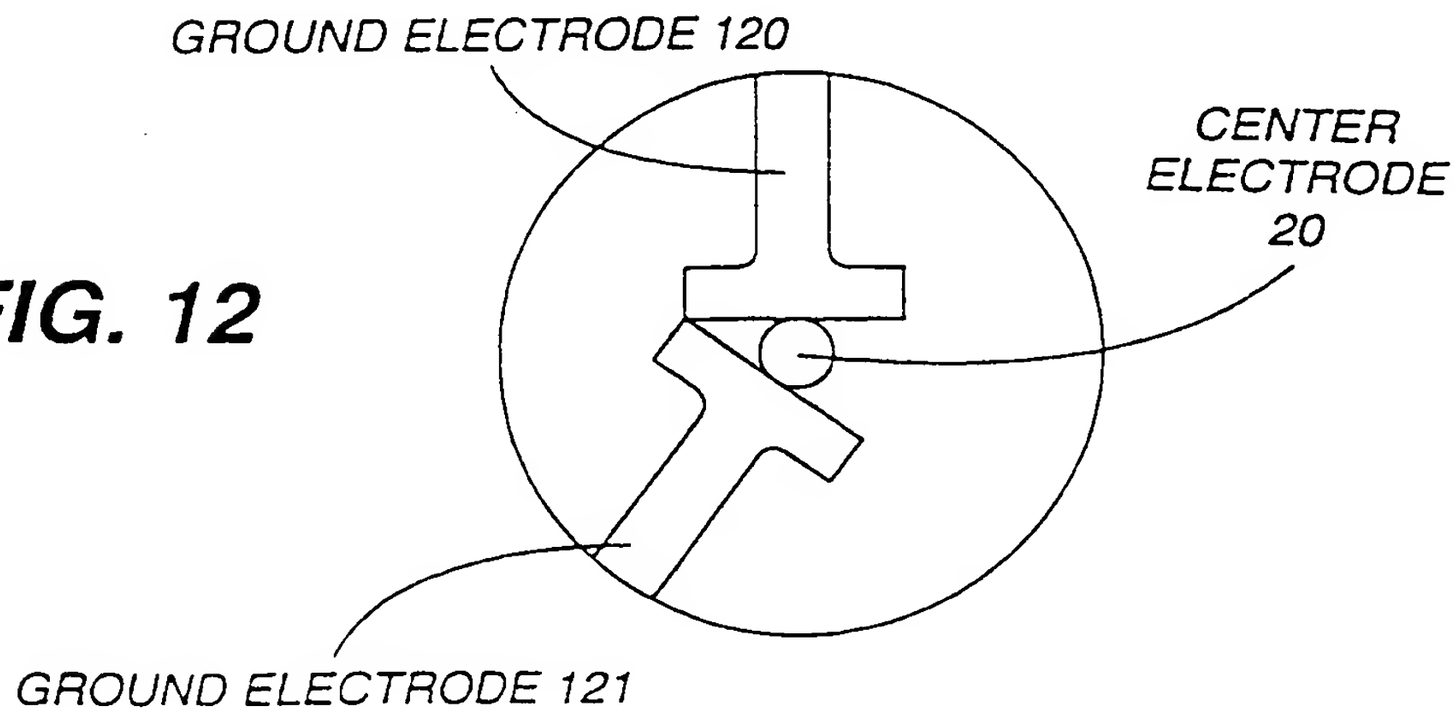


FIG. 12

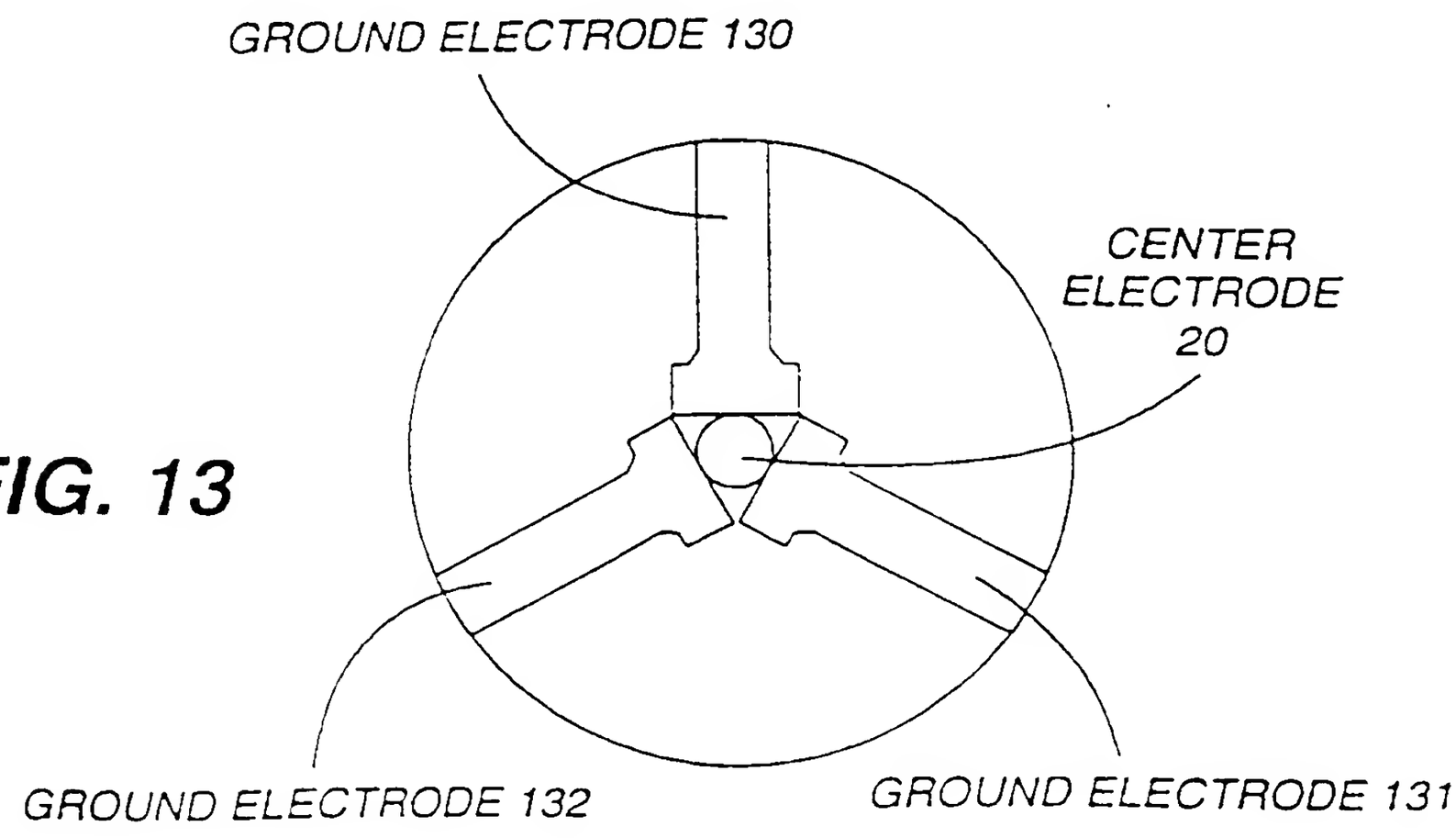


FIG. 13

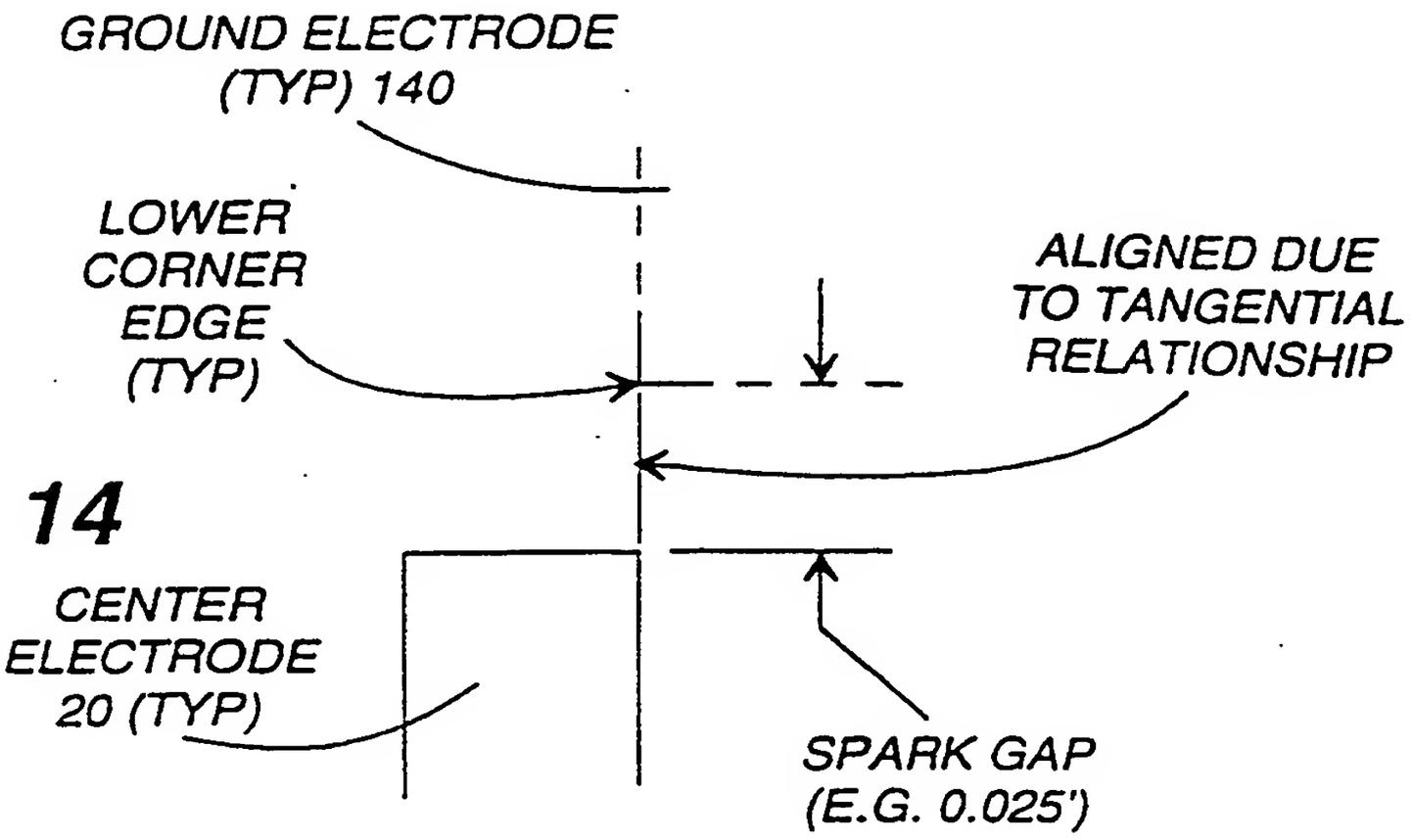


FIG. 14

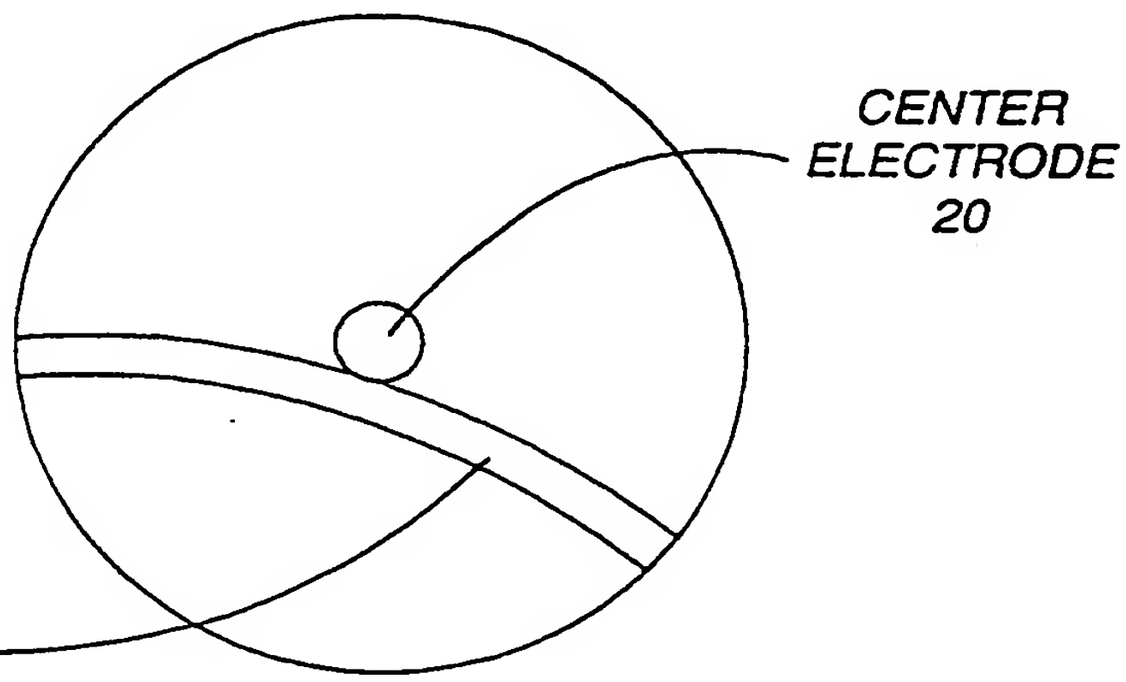


FIG. 15

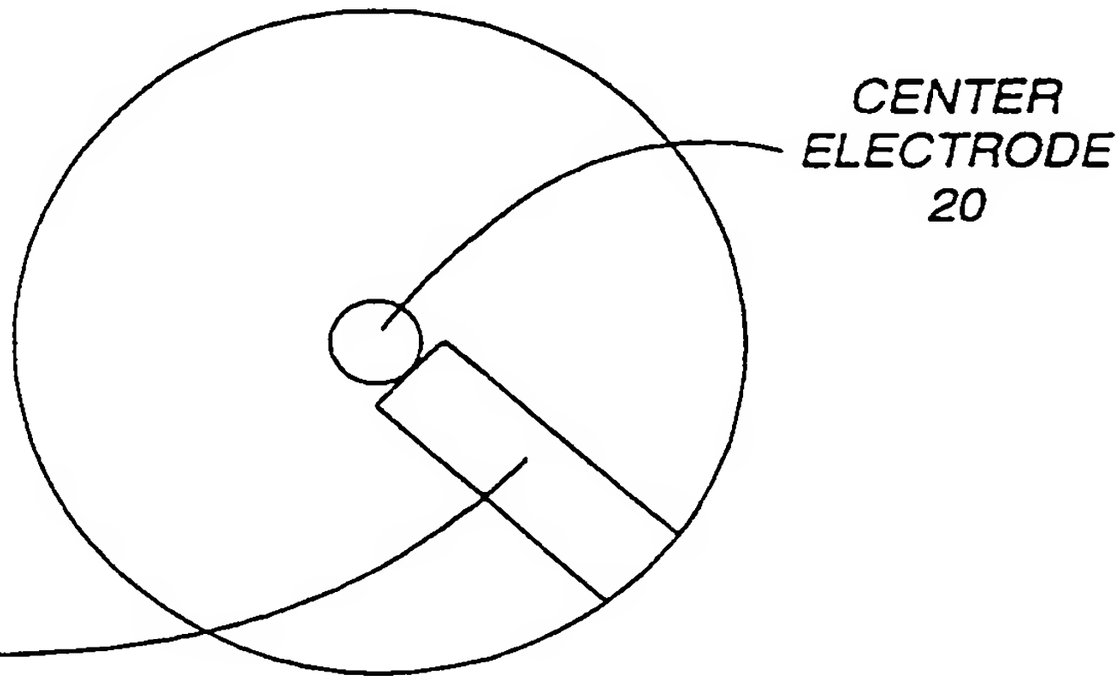


FIG. 16

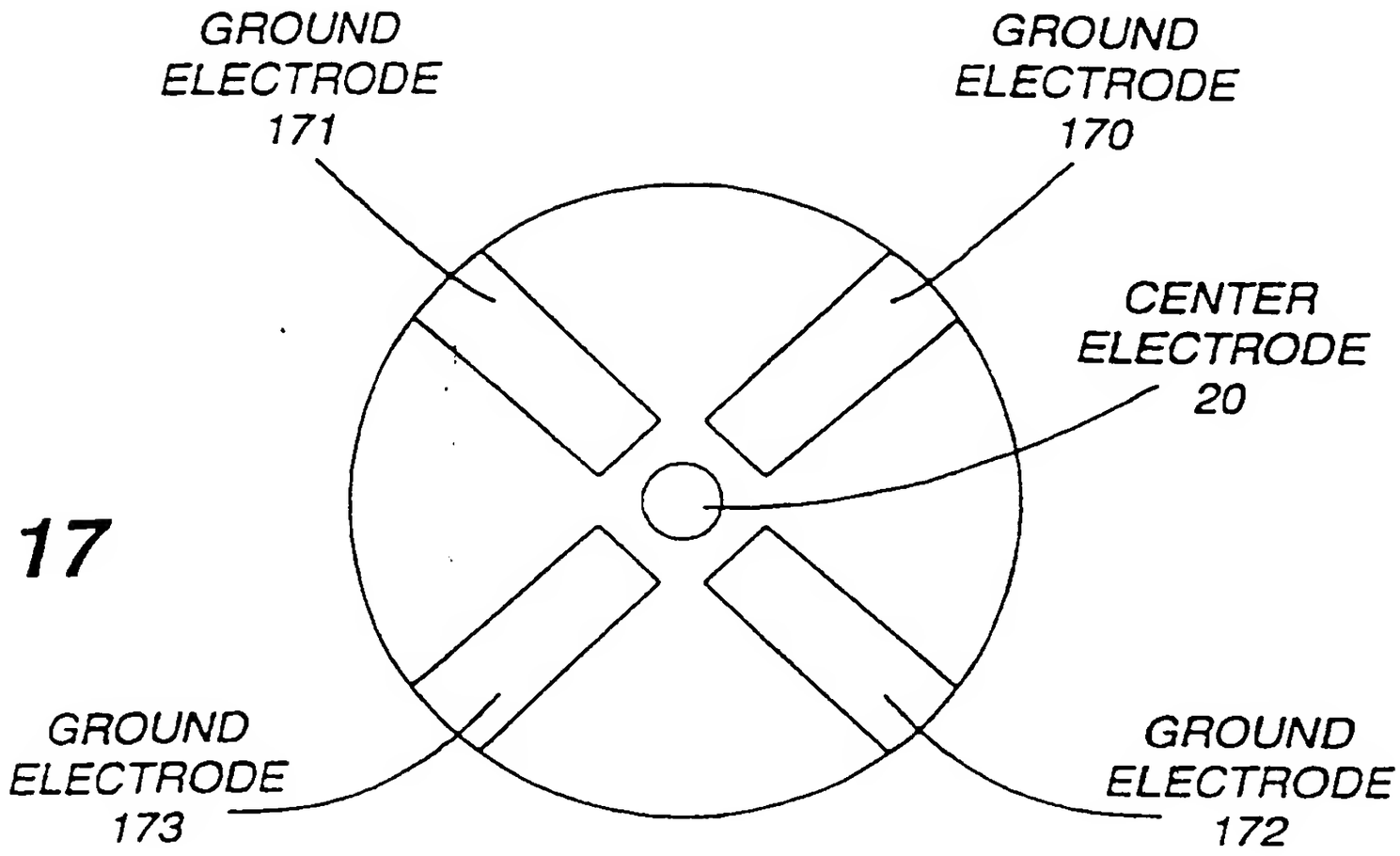


FIG. 17

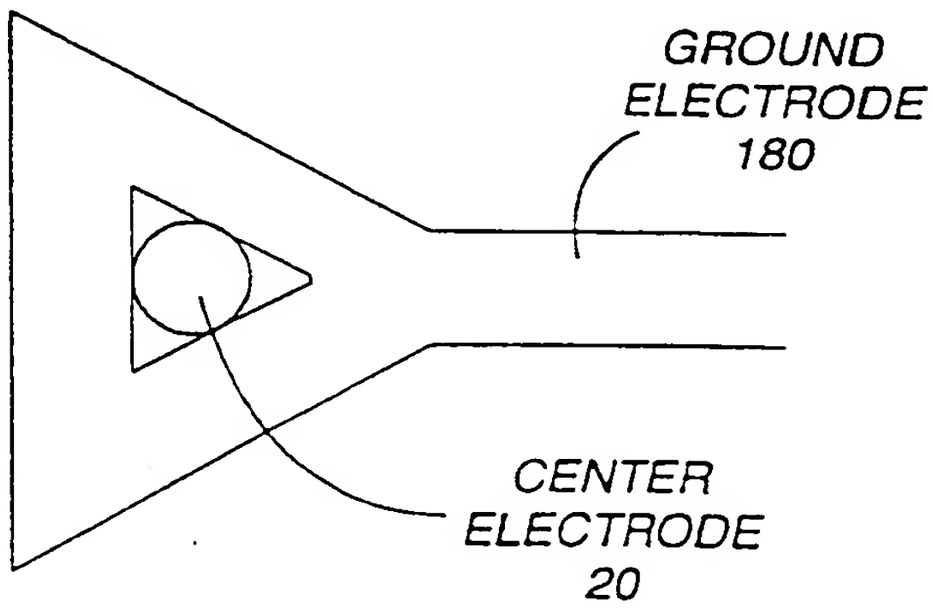


FIG. 18

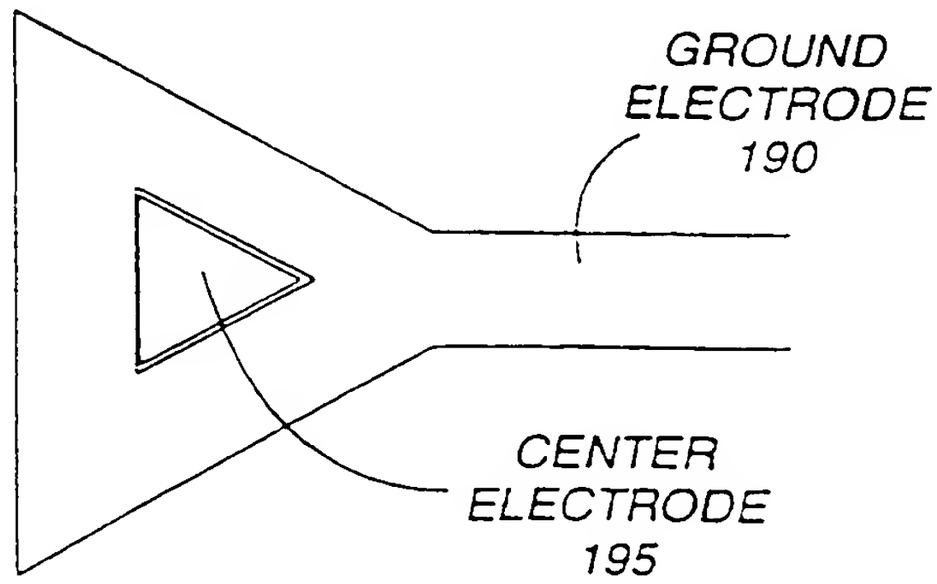


FIG. 19

FIG. 20

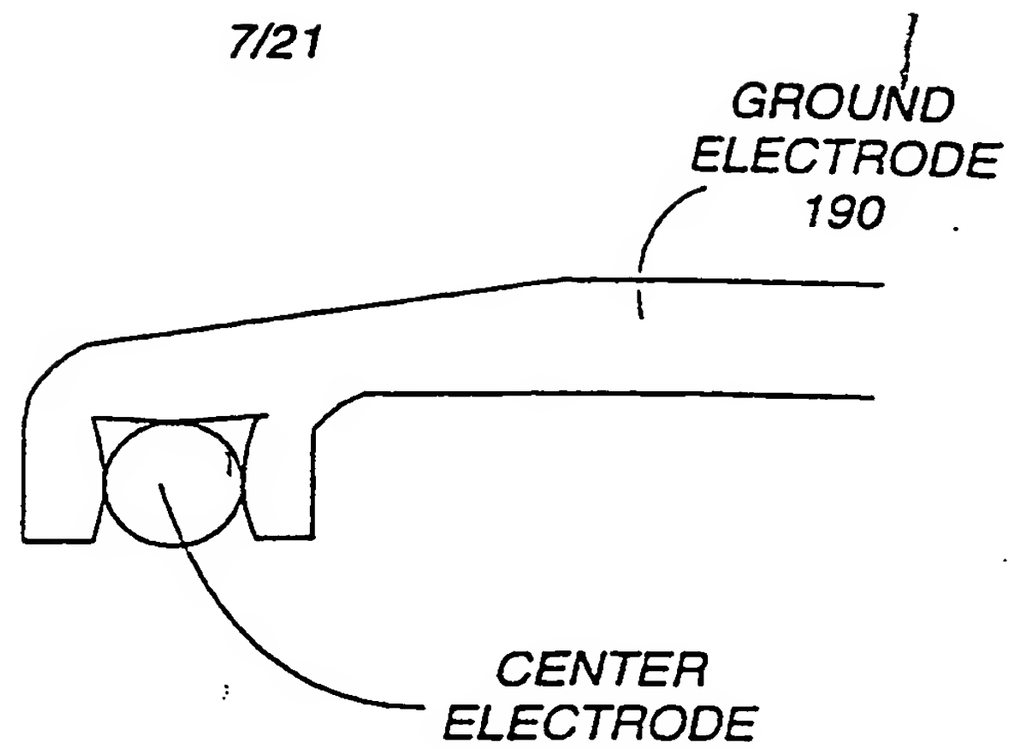


FIG. 21

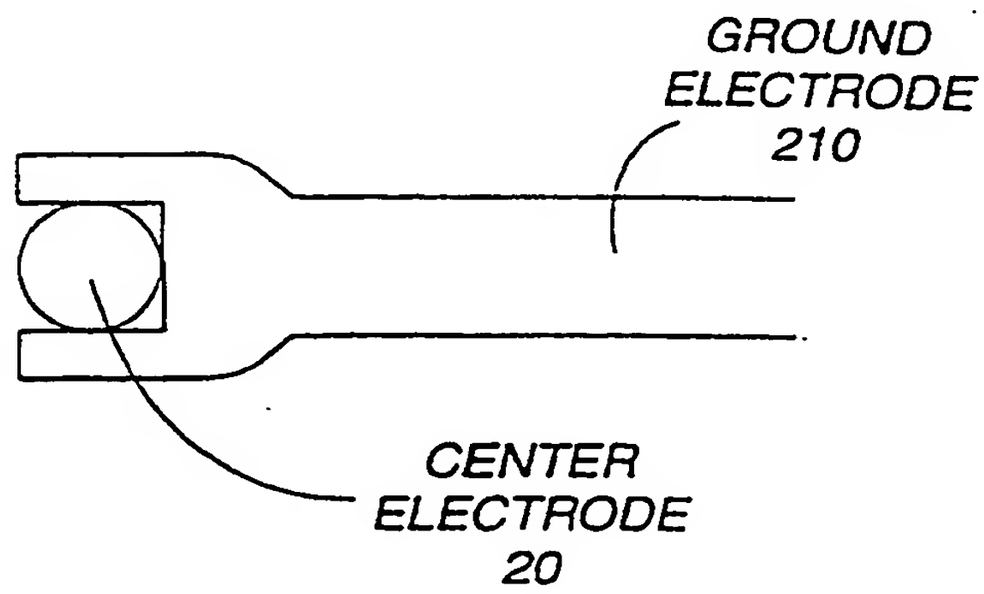


FIG. 22

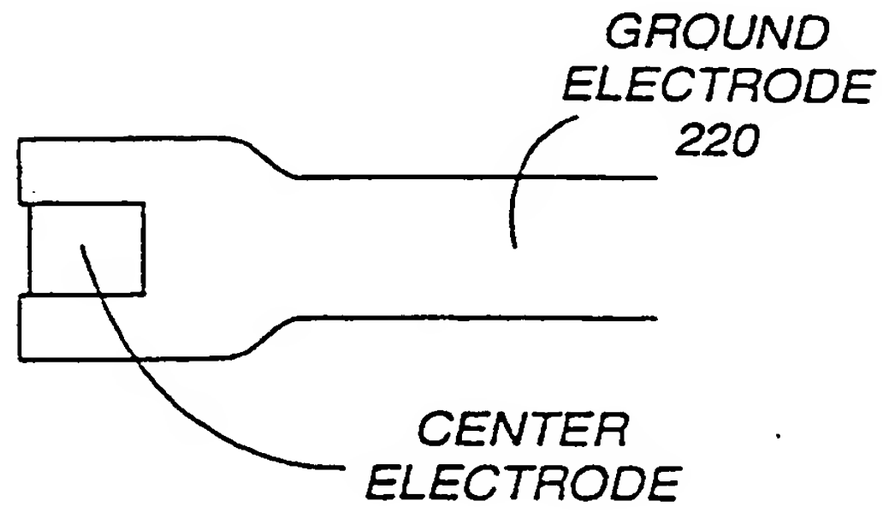
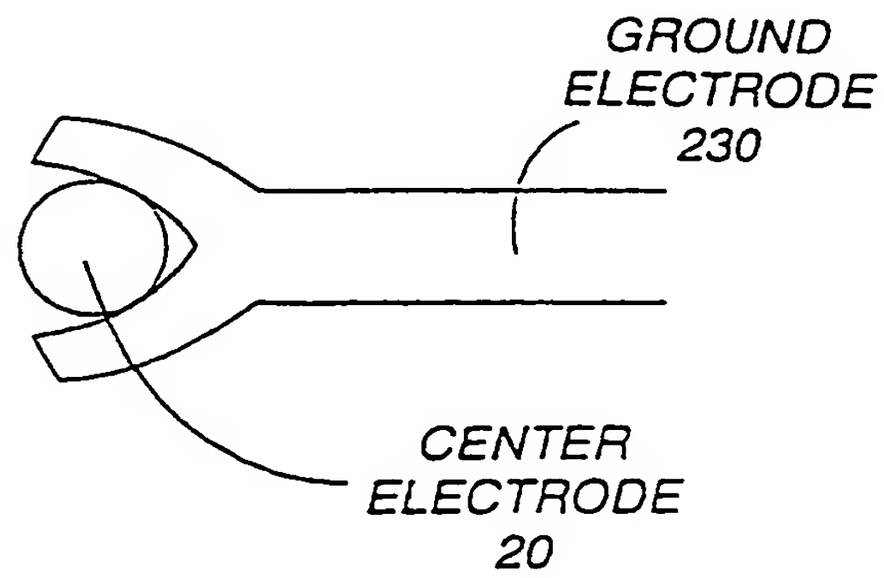


FIG. 23



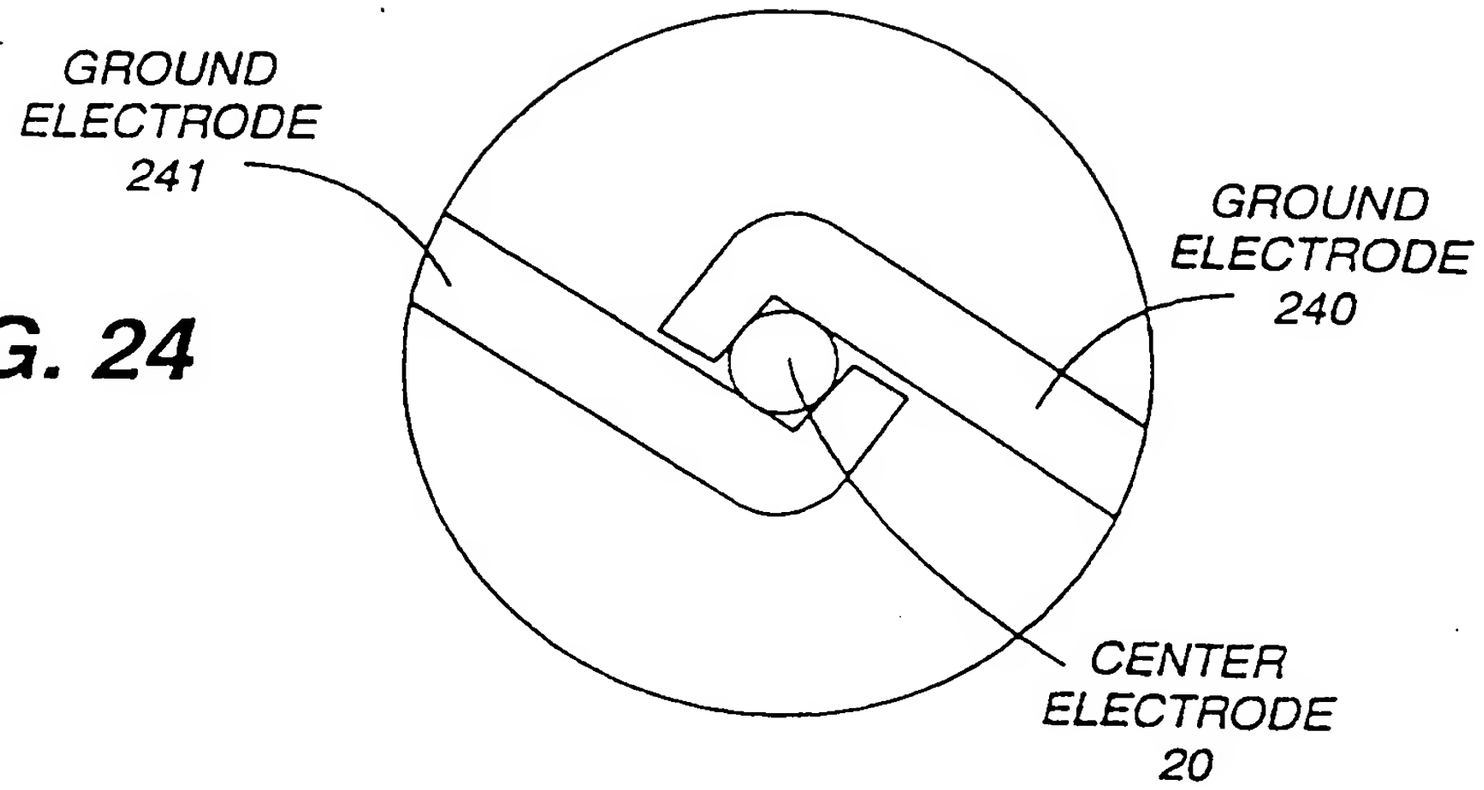

GROUND
ELECTRODE
241
GROUND
ELECTRODE
240
CENTER
ELECTRODE
20

FIG. 24

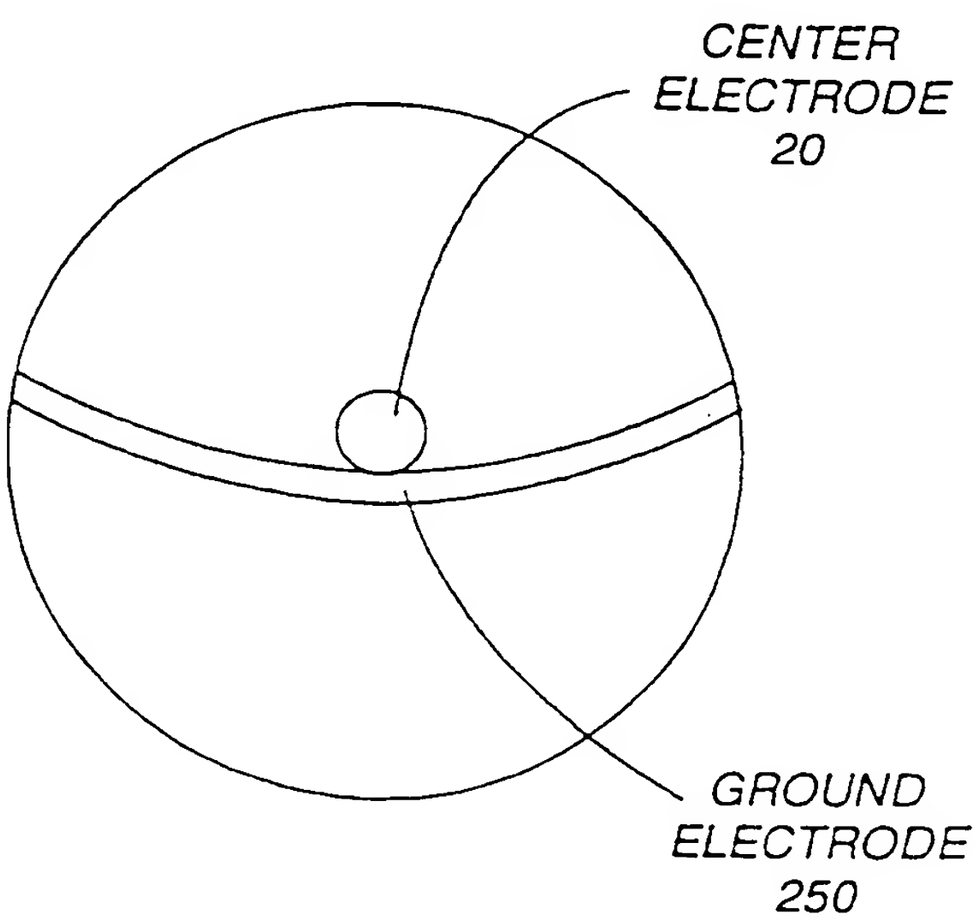
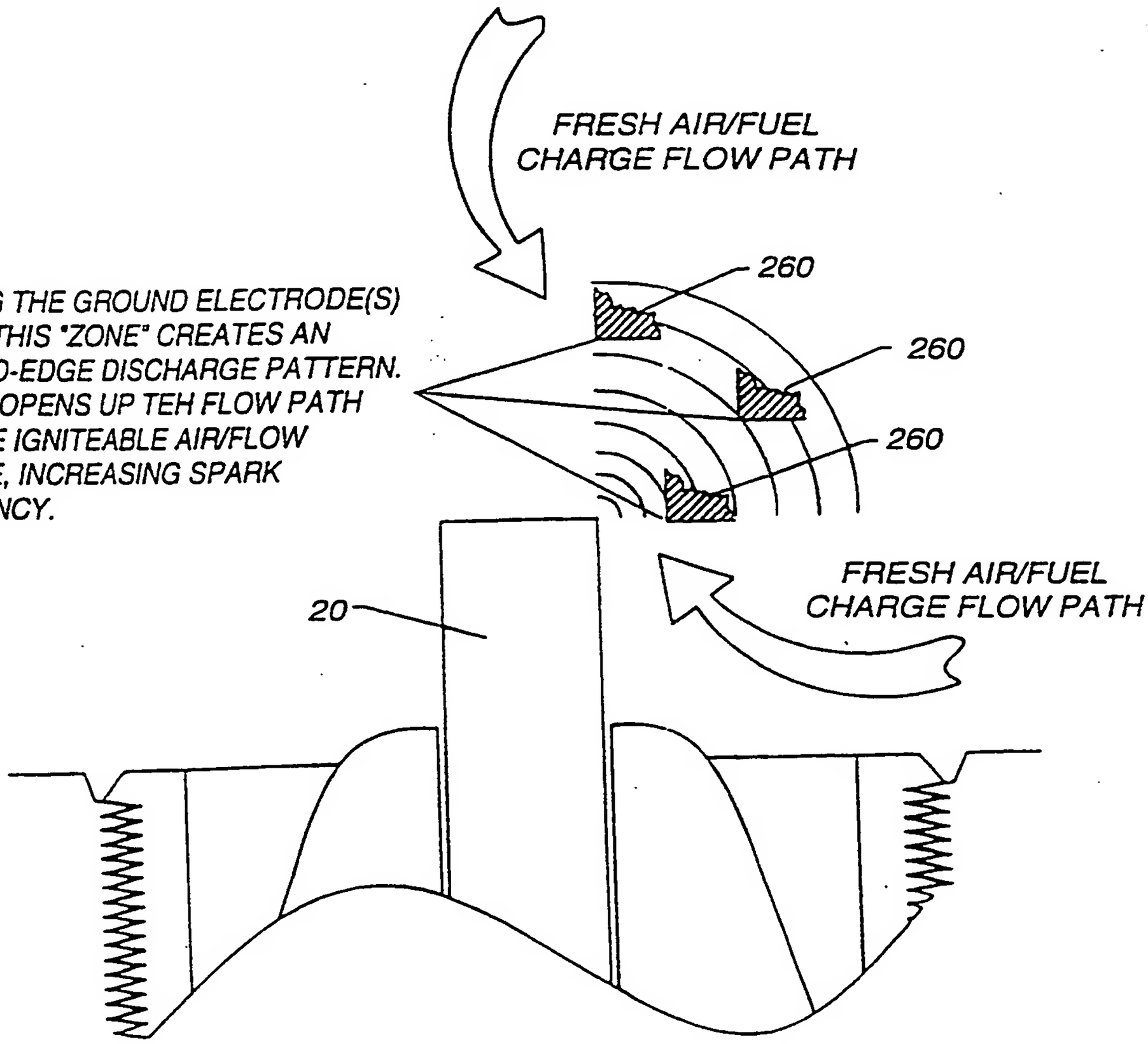

CENTER
ELECTRODE
20
GROUND
ELECTRODE
250

FIG. 25

GROUND ELECTRODE EDGE PLACEMENT ZONE
FOR MAXIMUM SPARK EFFICIENCY



PLACING THE GROUND ELECTRODE(S) WITHIN THIS "ZONE" CREATES AN EDGE-TO-EDGE DISCHARGE PATTERN. IT ALSO OPENS UP TEH FLOW PATH FOR THE IGNITEABLE AIR/FLOW CHARGE, INCREASING SPARK EFFICIENCY.

FIG. 26

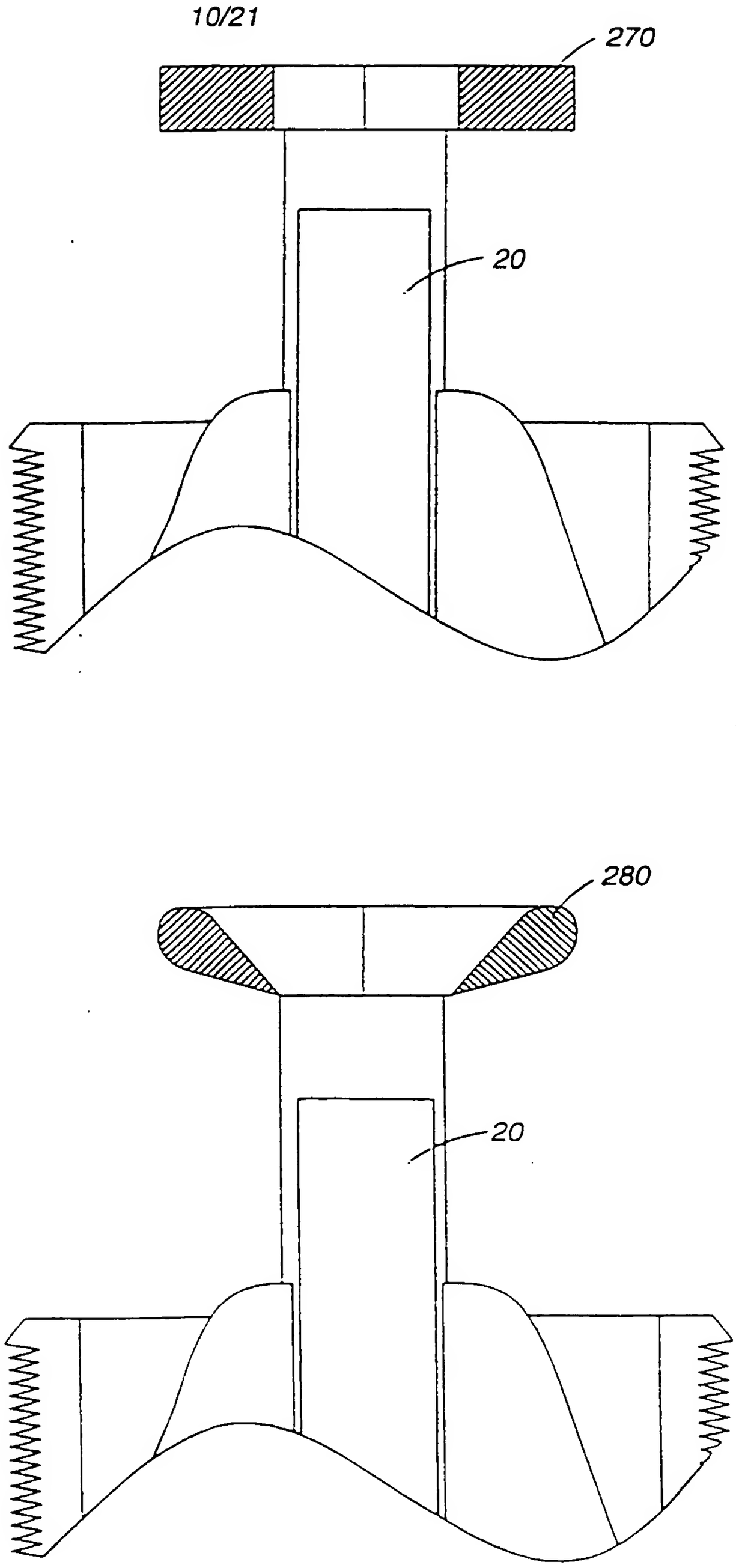


FIG. 27

FIG. 28

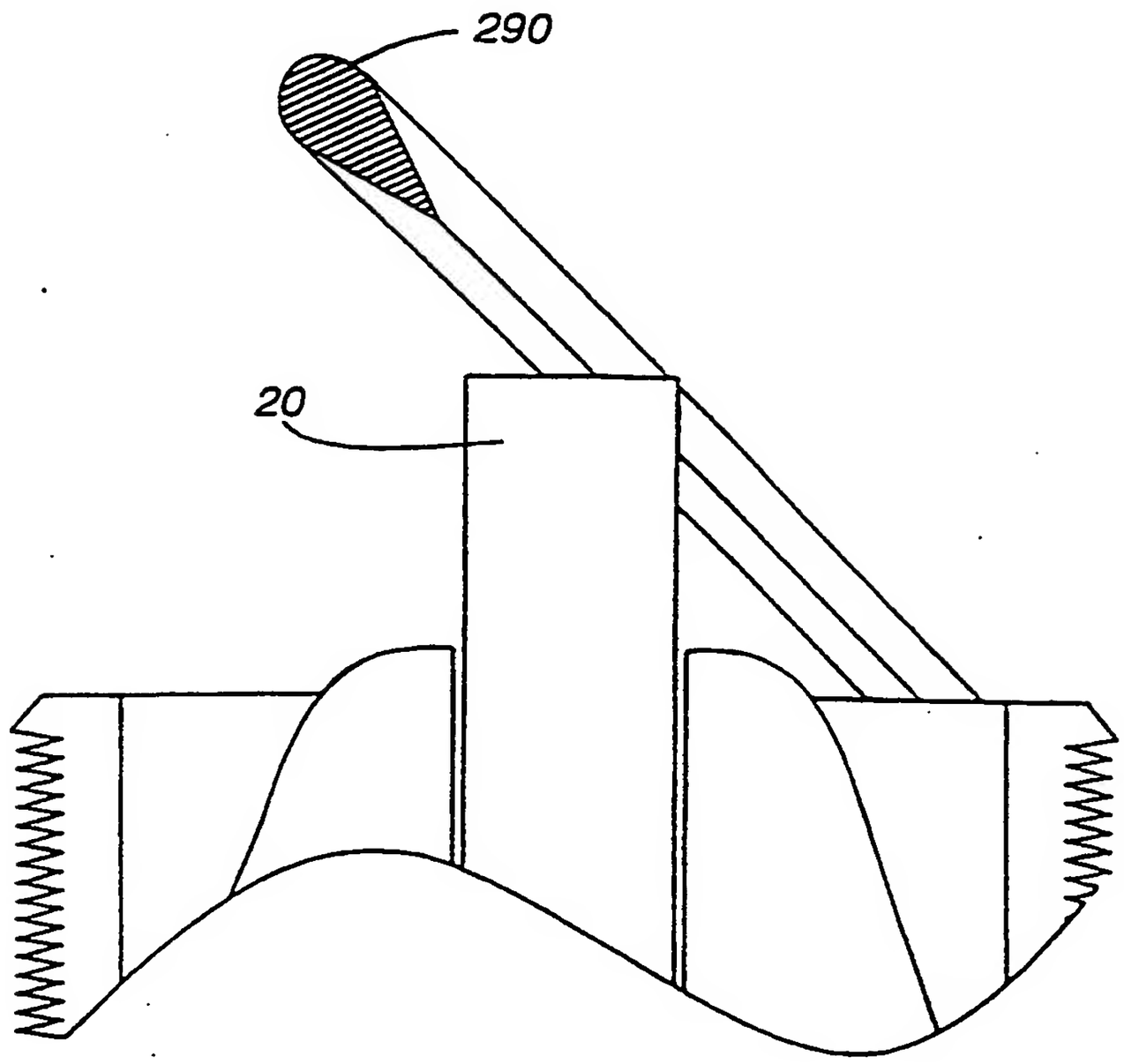


FIG. 29

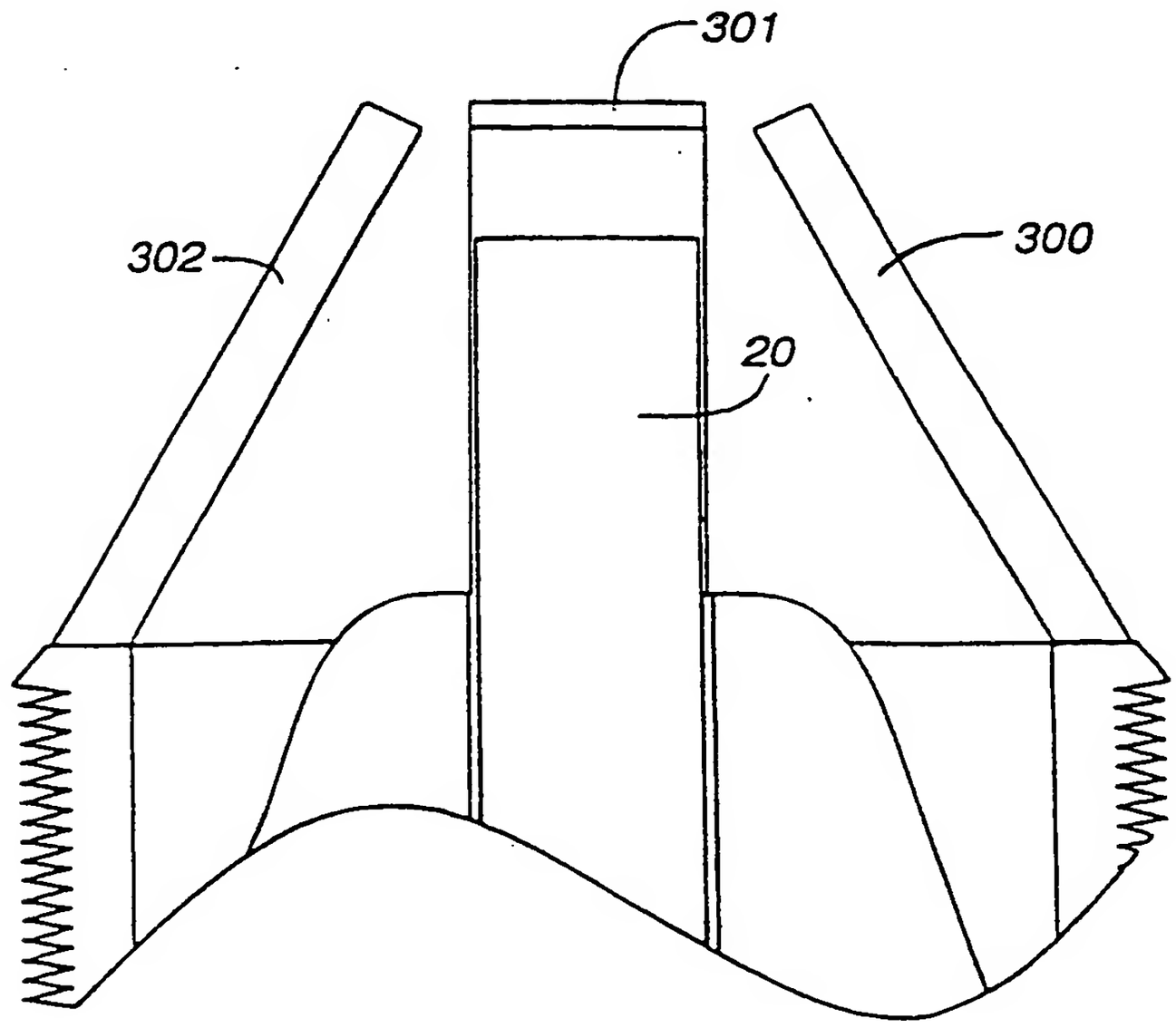


FIG. 30

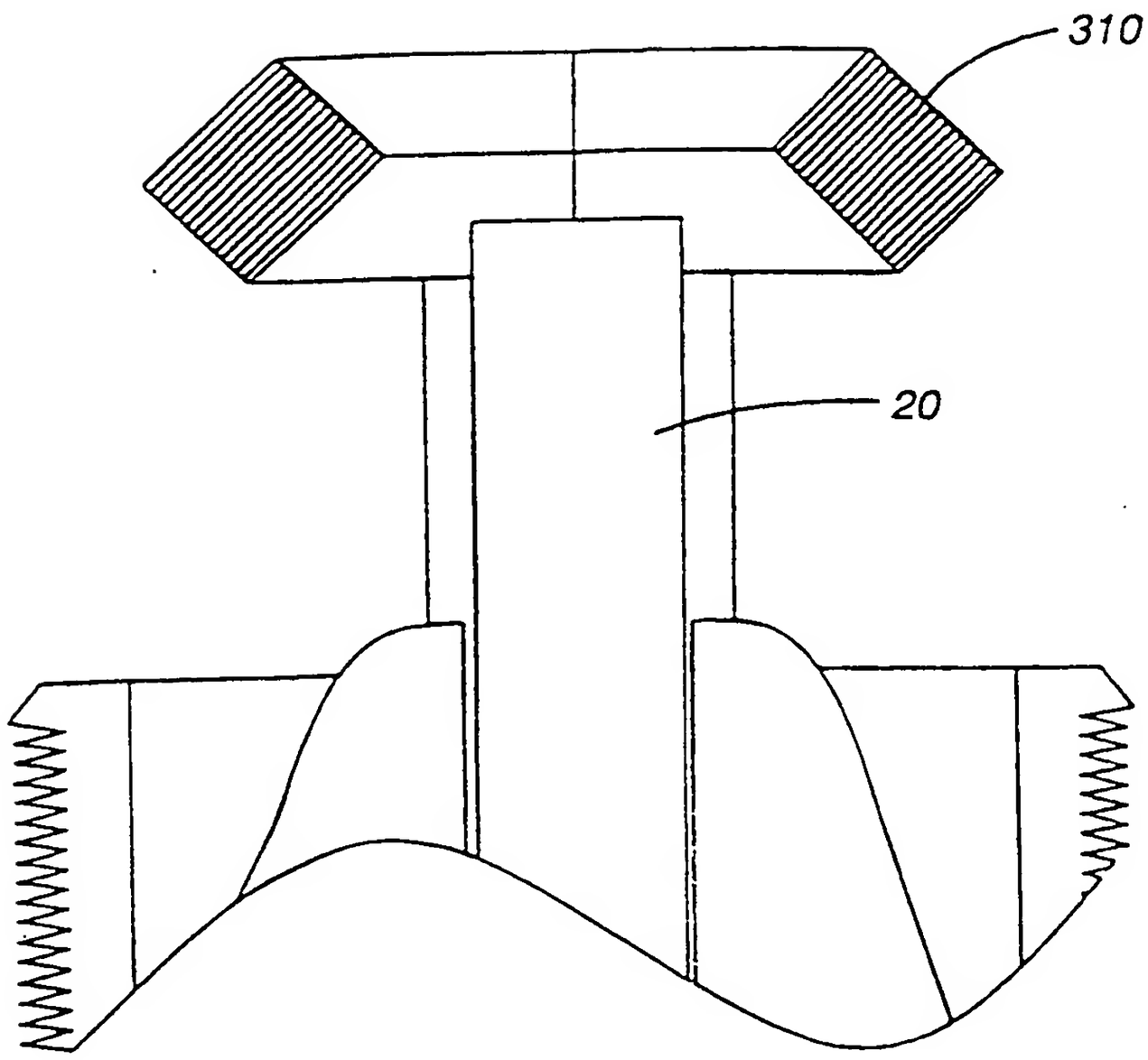


FIG. 31

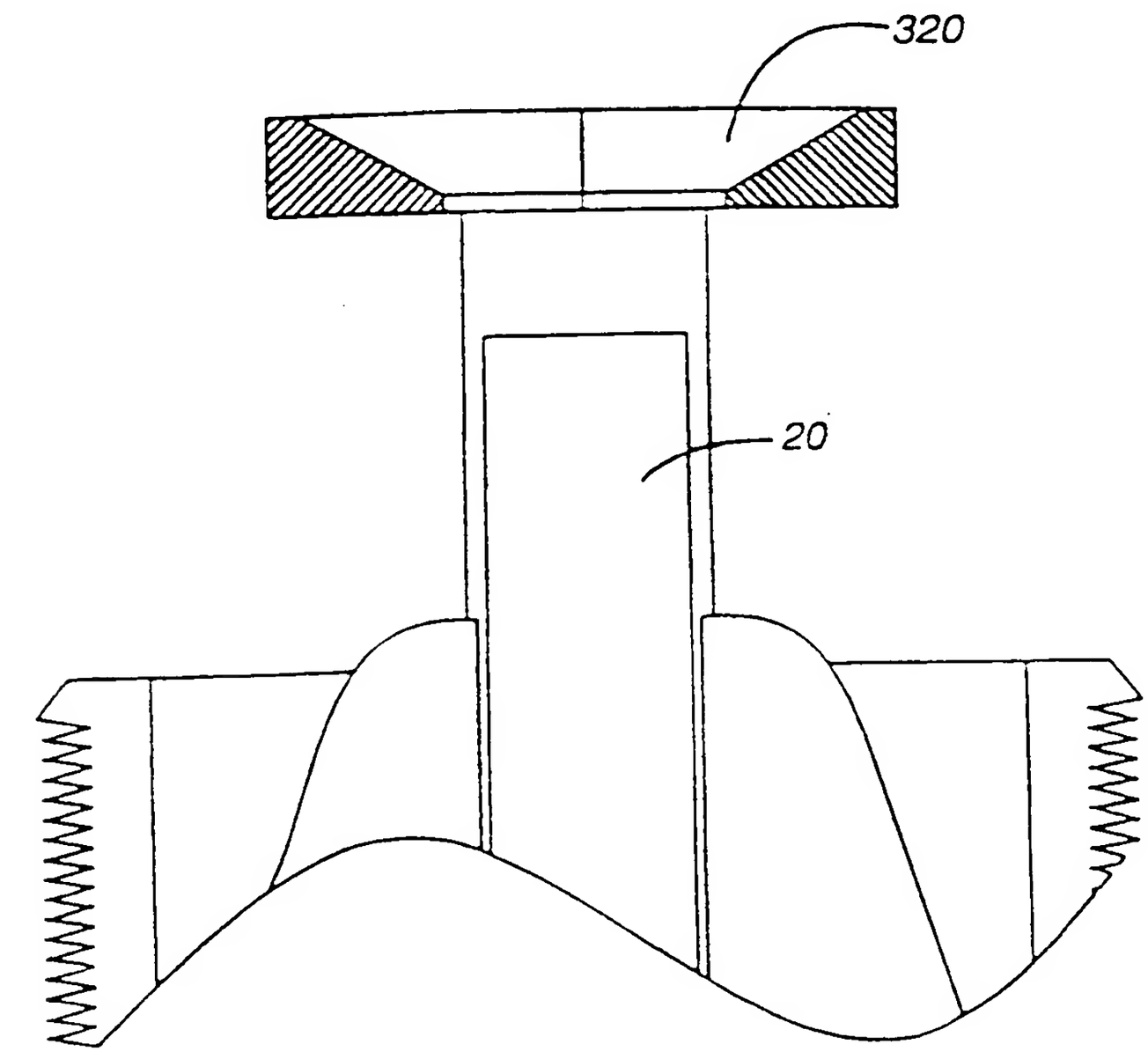


FIG. 32

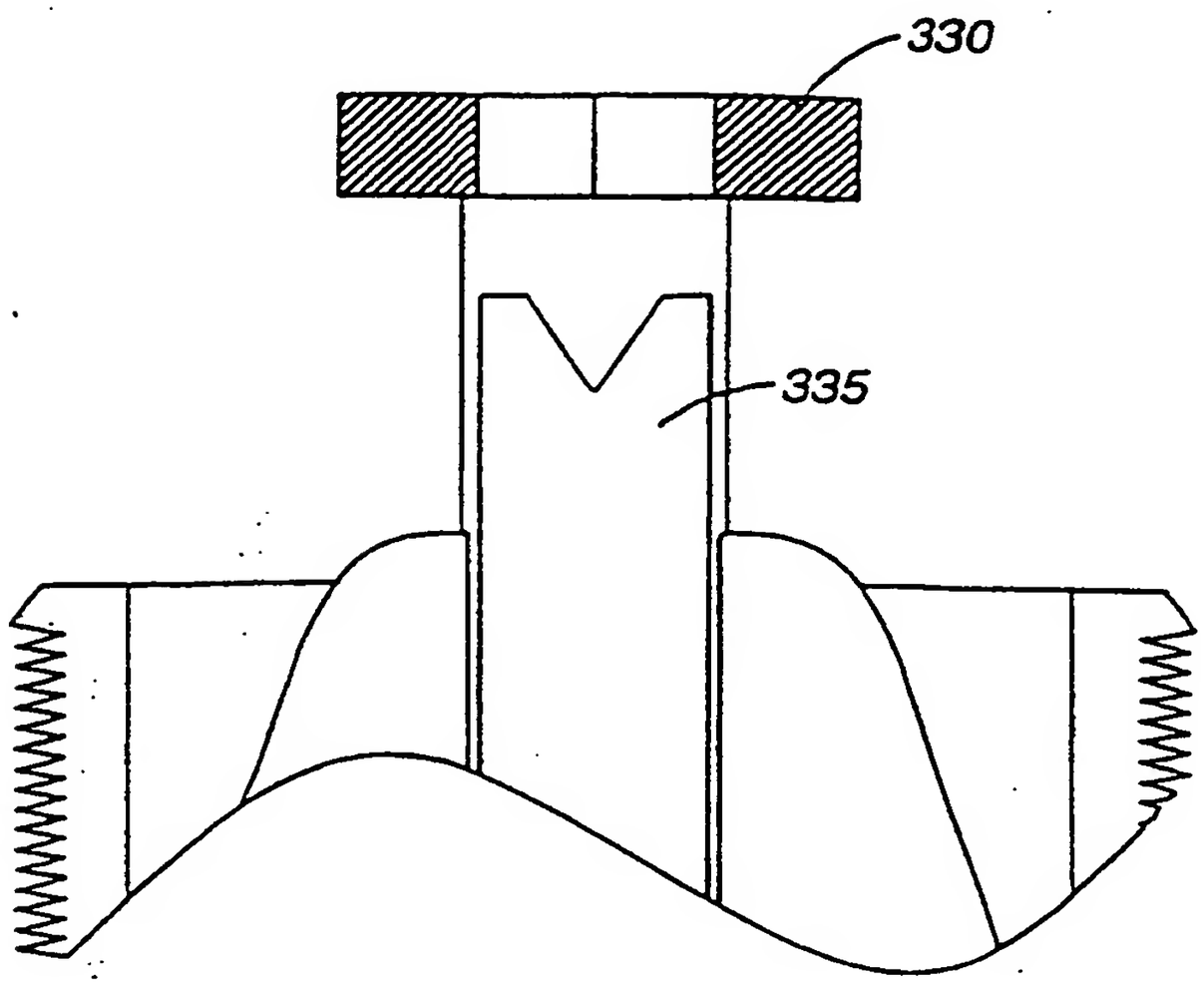


FIG. 33

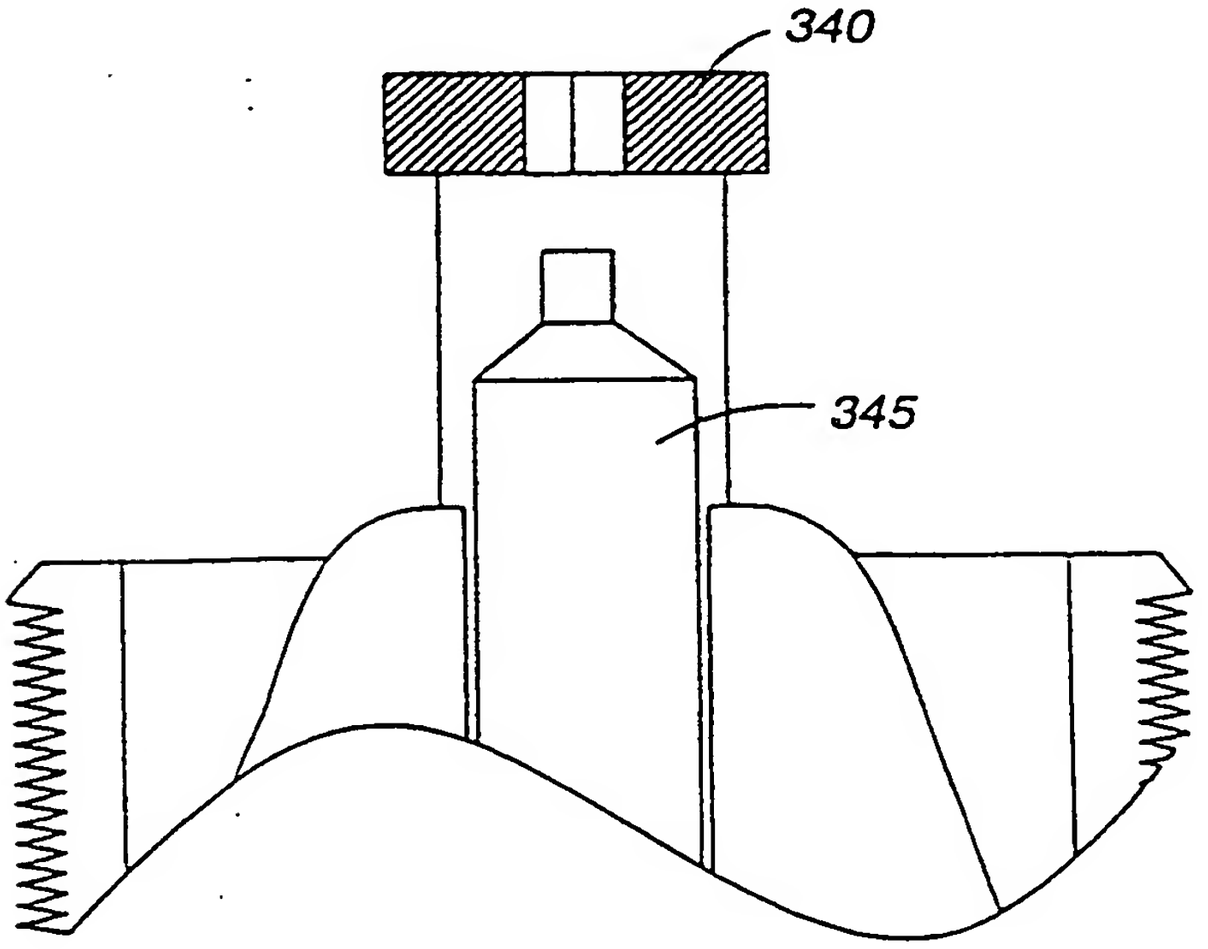


FIG. 34

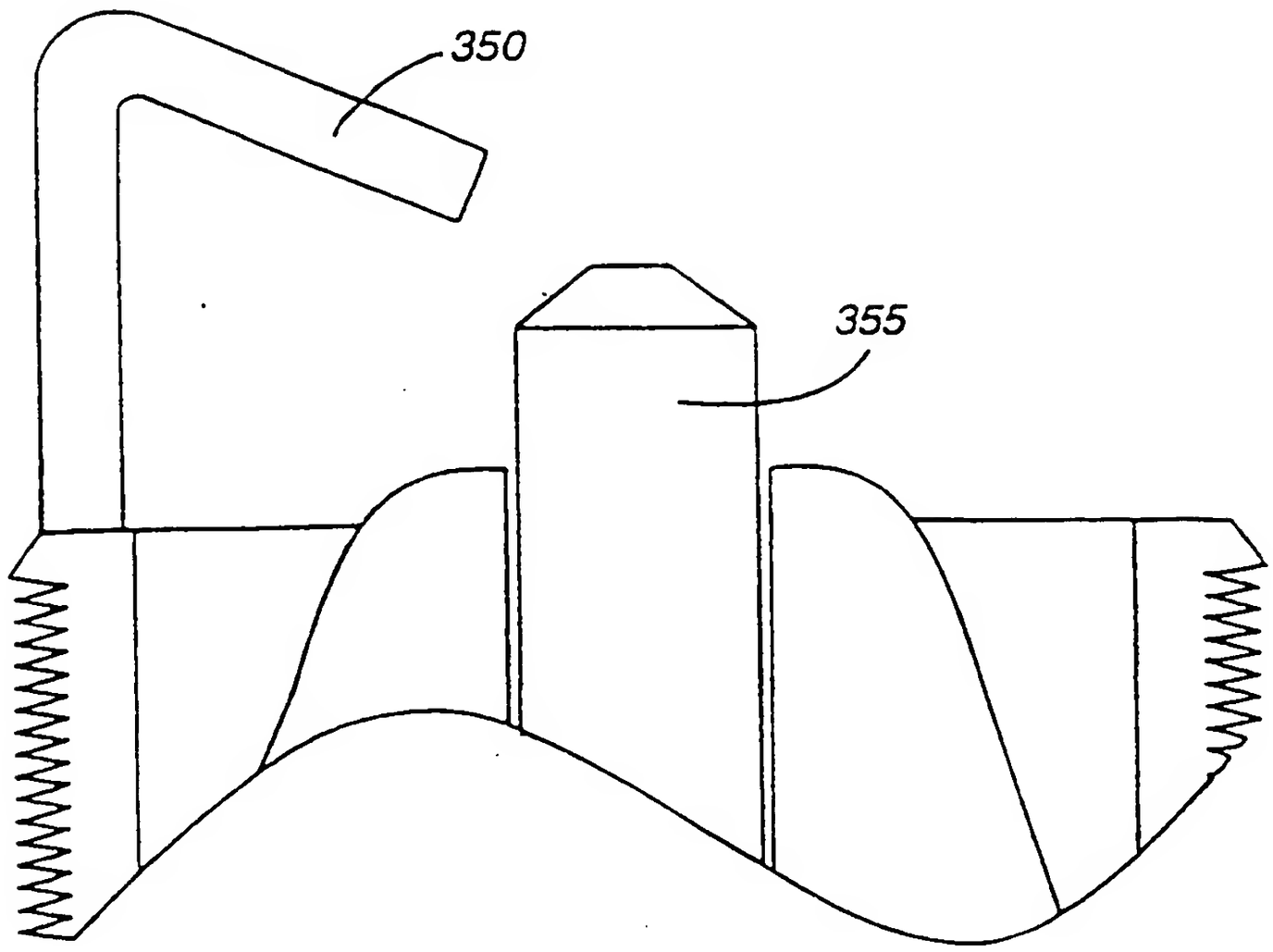


FIG. 35

FIG. 36

MAXIMIZED EDGE-TO-EDGE PRESENTATION

THIS DESIGN TAKES FULL ADVANTAGE OF THE EDGE-TO-EDGE DISCHARGE PHENOMENA. WHILE MORE EXPENSIVE TO MANUFACTURE THAN OTHER EMBODIMENTS, THIS DESIGN PRESENTS THE LATEST SHIELDED EDGE-TO-EDGE SPARK TO THE COMBUSTION CHAMBER. THE SMALL SIZES OF THE ELECTRODES ALSO SERVES TO REDUCE BLOCKAGE TO THE INCOMING FUEL CHARGE AND THE EXITING FLAME KERNEL.

CHISEL POINT CENTER ELECTRODE

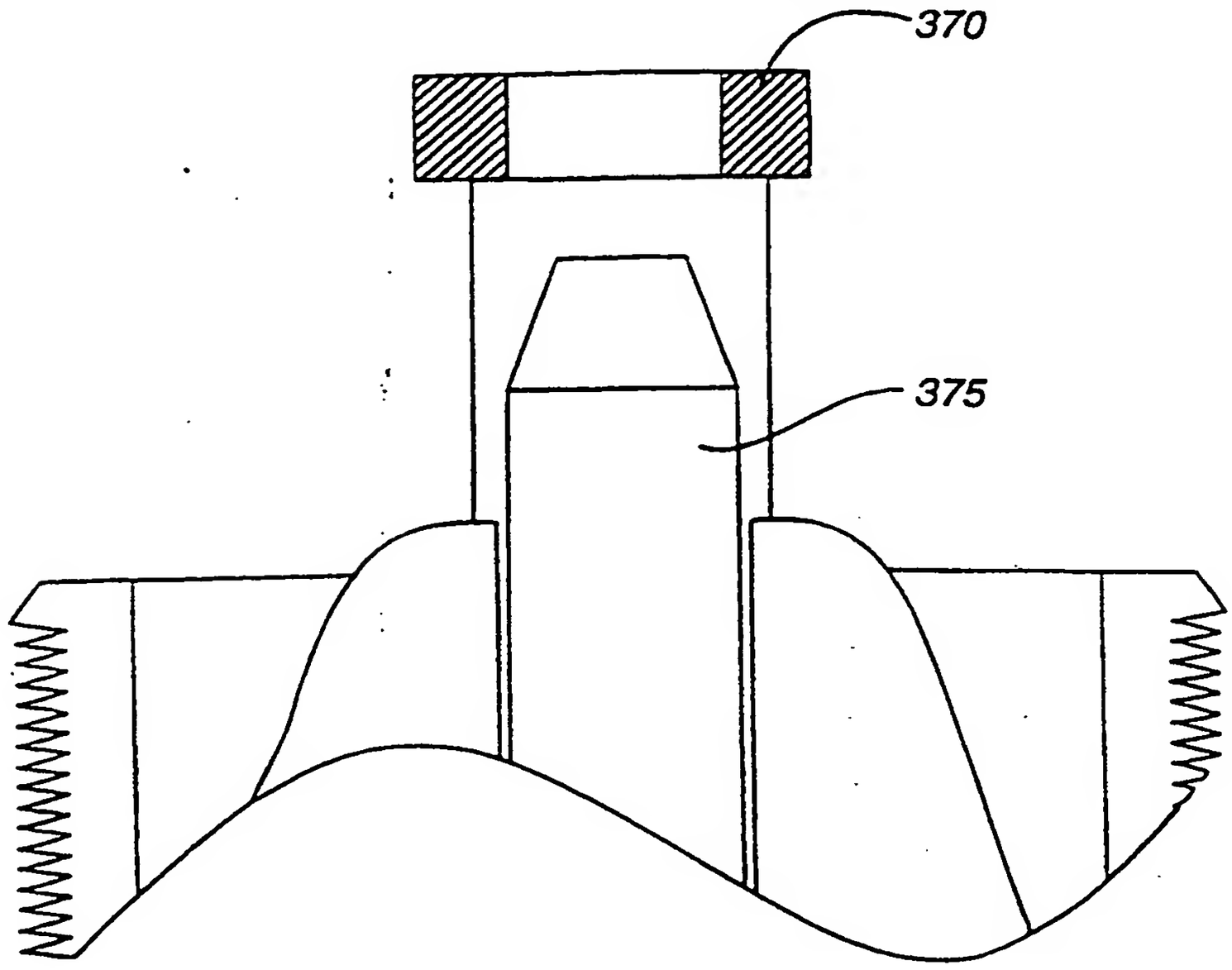


FIG. 37

SINGLE POINT CENTER ELECTRODE
STRIKING TO ELEVATED EDGE

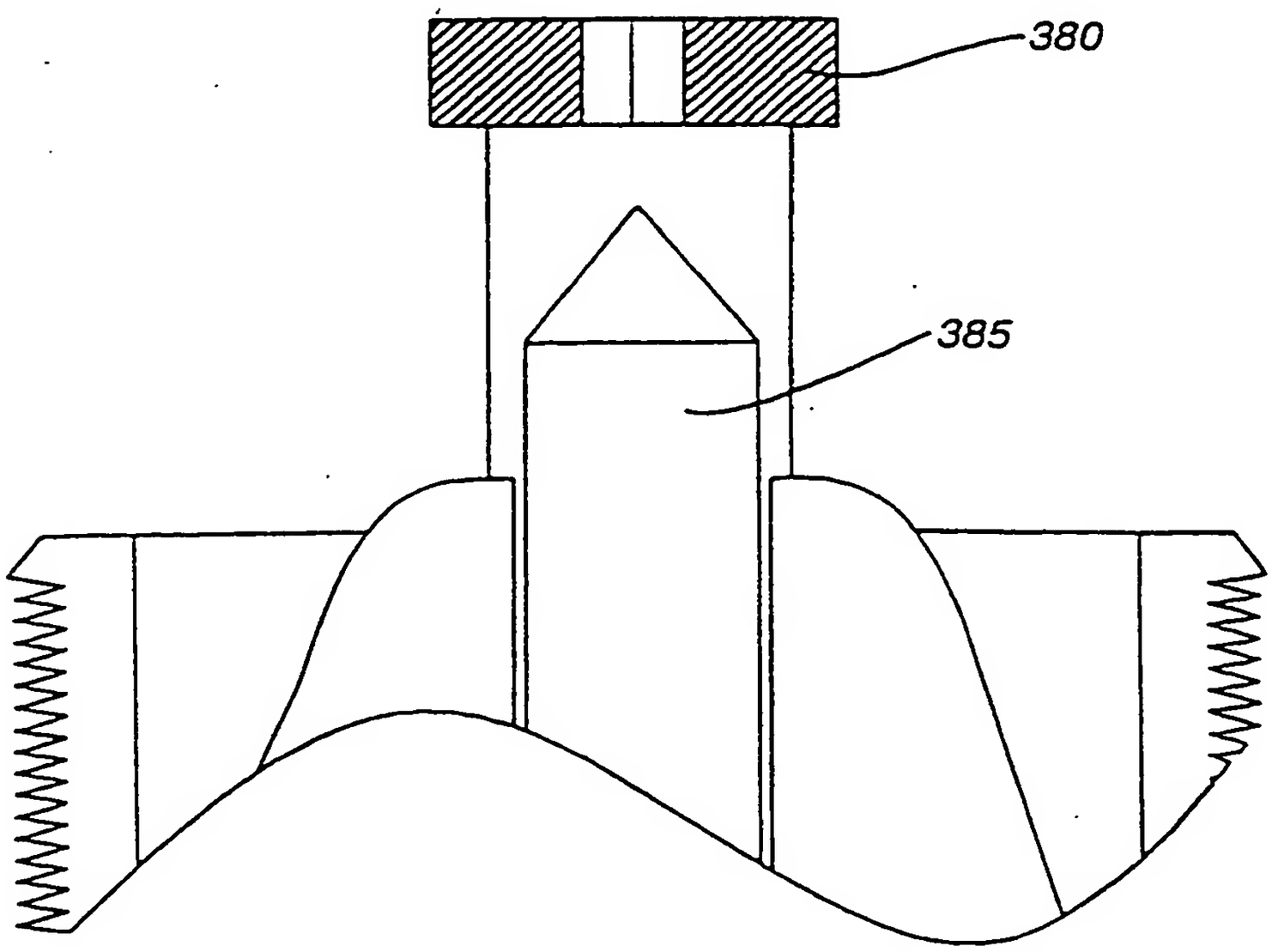
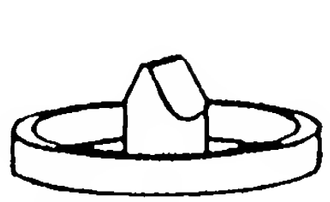
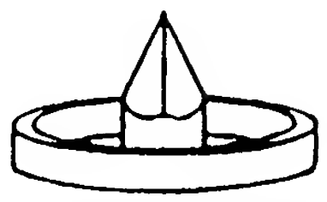


FIG. 38

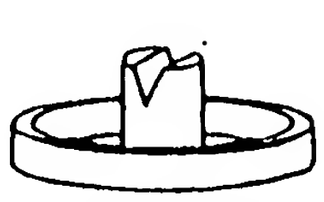
CENTER ELECTRODE EDGES
CONTINUING THE EDGE-TO-EDGE INVENTION, THE CENTER ELECTRODE CAN HAVE EDGES INTRODUCED INTO ITS DESIGN THAT BENEFIT SPARK FORMATION. THERE ARE MULTIPLE WAYS TO PLACE EDGES IN THE CENTER ELECTRODE DESIGN. IN EACH CASE, THE PRESENTED EDGE(S) OF THE GROUND ELECTRODE CREATE A EDGE-TO-EDGE STRIKING ZONE BETWEEN THE GROUND AND CENTER ELECTRODE.



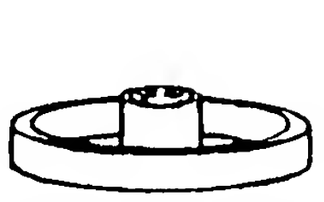
CHISEL POINT
395-A



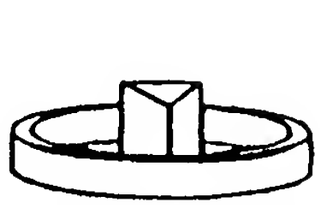
PYRAMID POINT
395-B



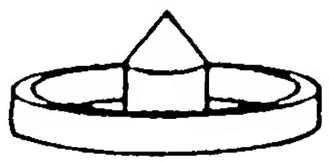
V-GROVE
395-C



DIMPLED CENTER
395-D

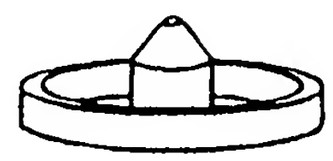


POLYGON
395-E

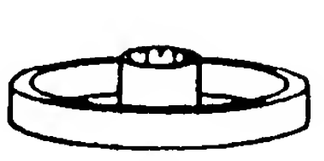


SINGLE POINT
395-F

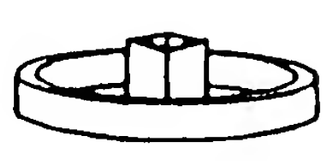
MULTIPLE EDGES
395-G



CHAMFER POINT
395-H

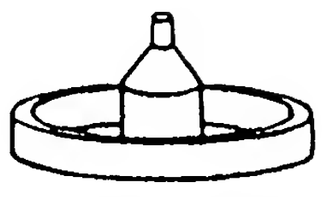


HOLLOW CYLINDER
395-I



HOLLOW POLYGON
395-J

FIG. 39



NECKED-DOWN
395-K

FIG. 40A

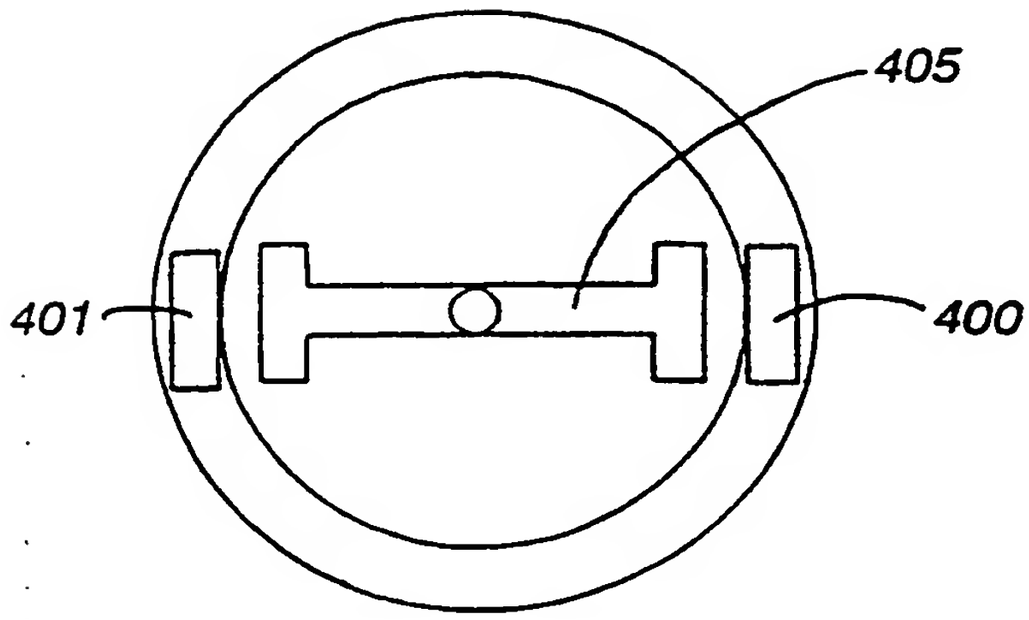


FIG. 40B

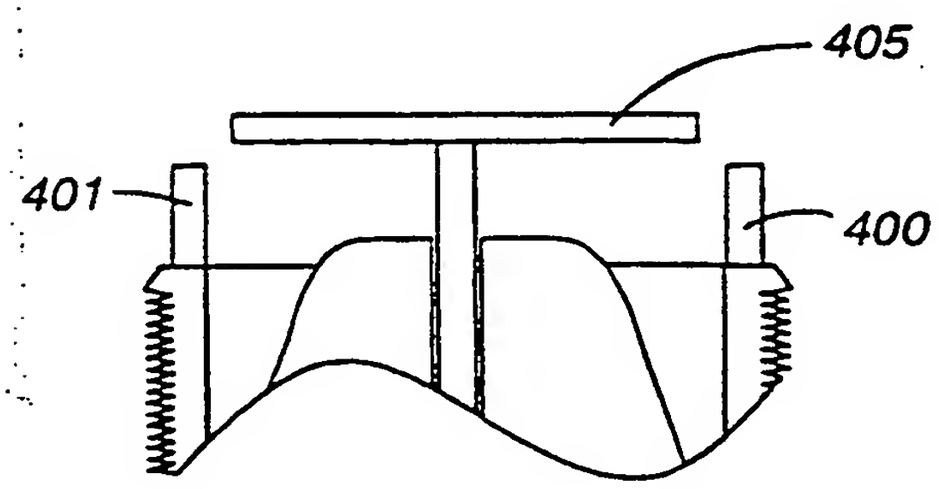


FIG. 41A

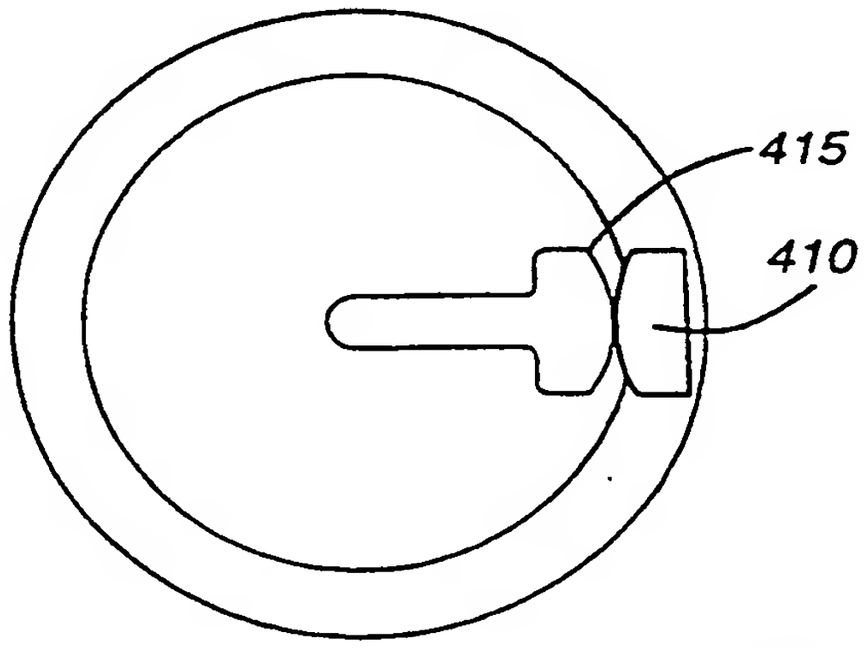
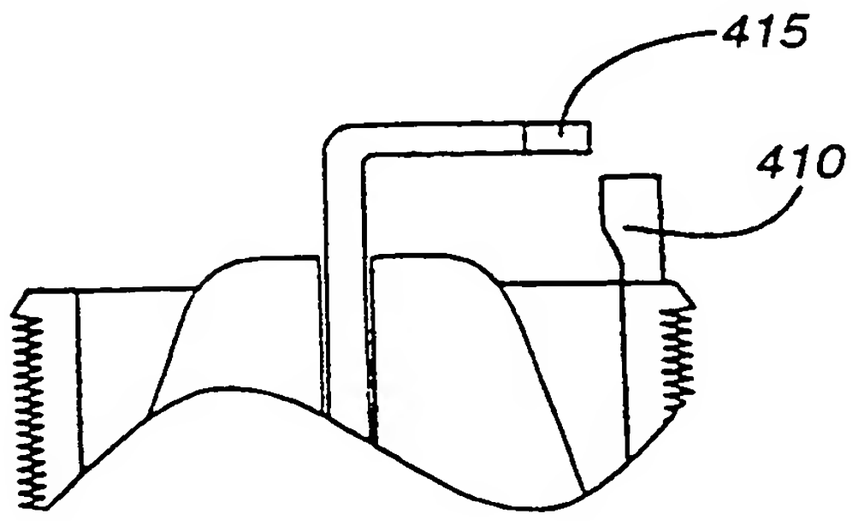


FIG. 41B



ELECTRODES CAN BE PLACED IN A SIDEWAYS POSITION, MAINTAINING THE EDGE TO EDGE RELATIONSHIP BETWEEN THE CENTER ELECTRODE AND GROUND ELECTRODE.

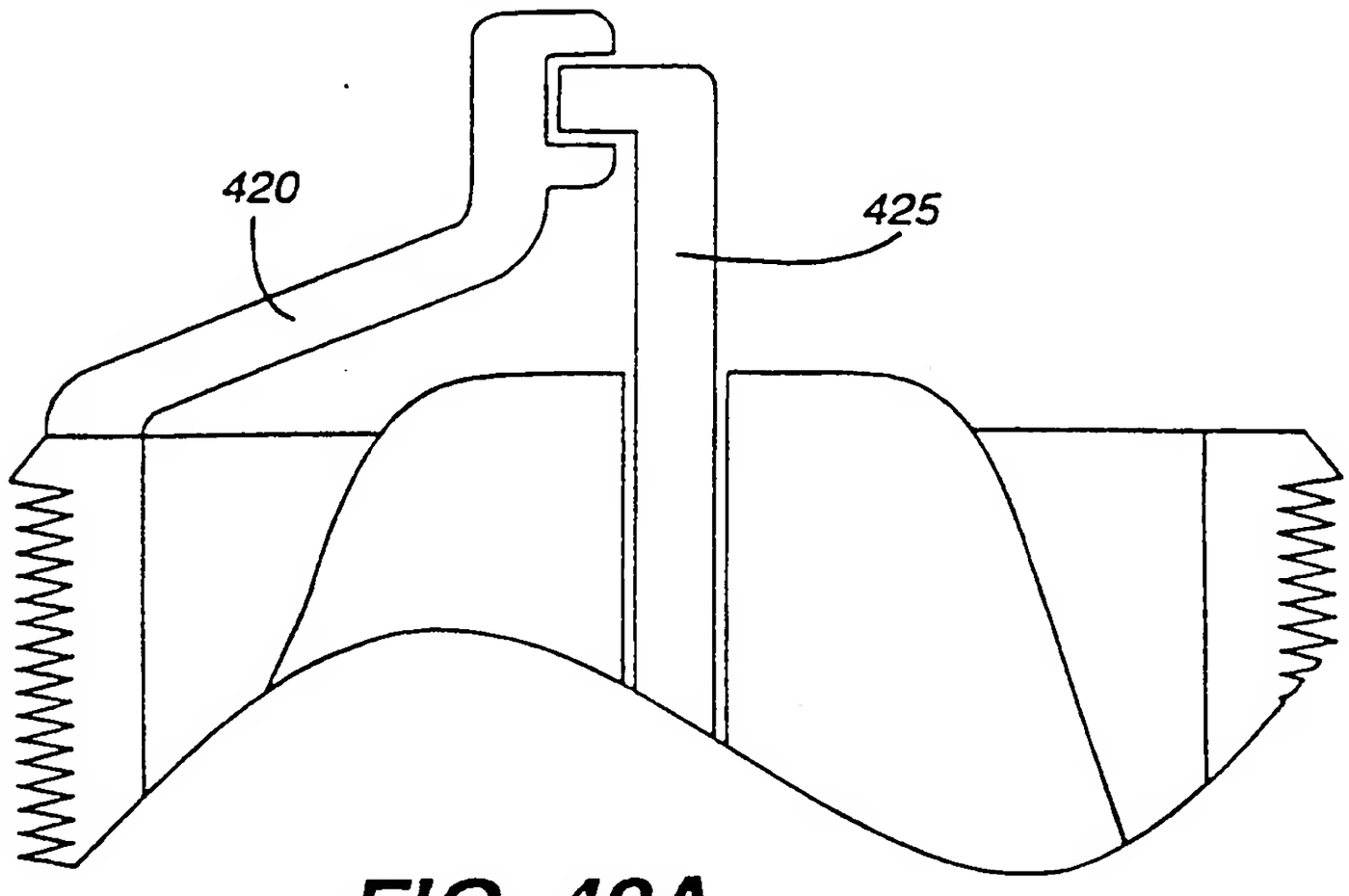


FIG. 42A

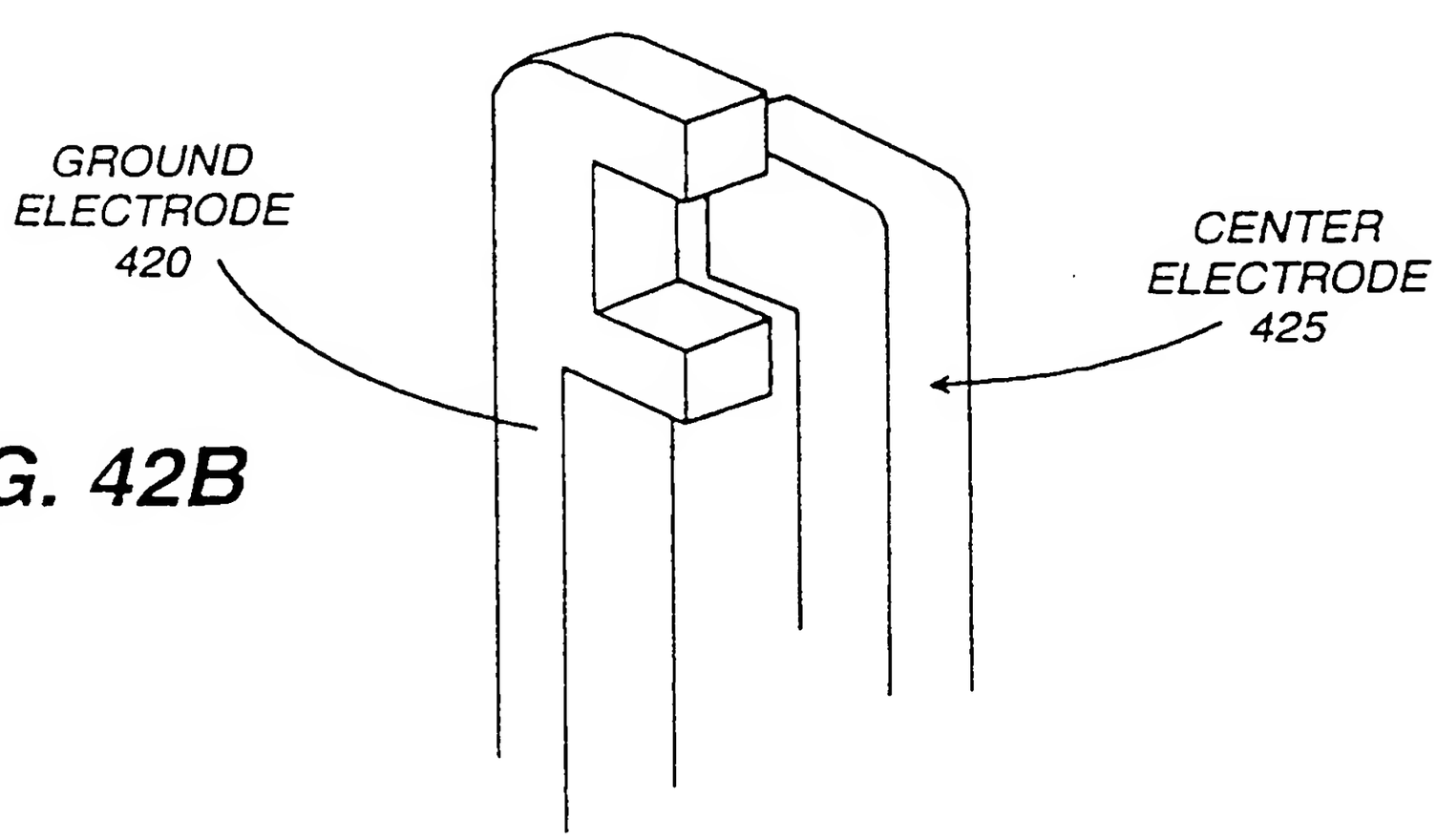


FIG. 42B

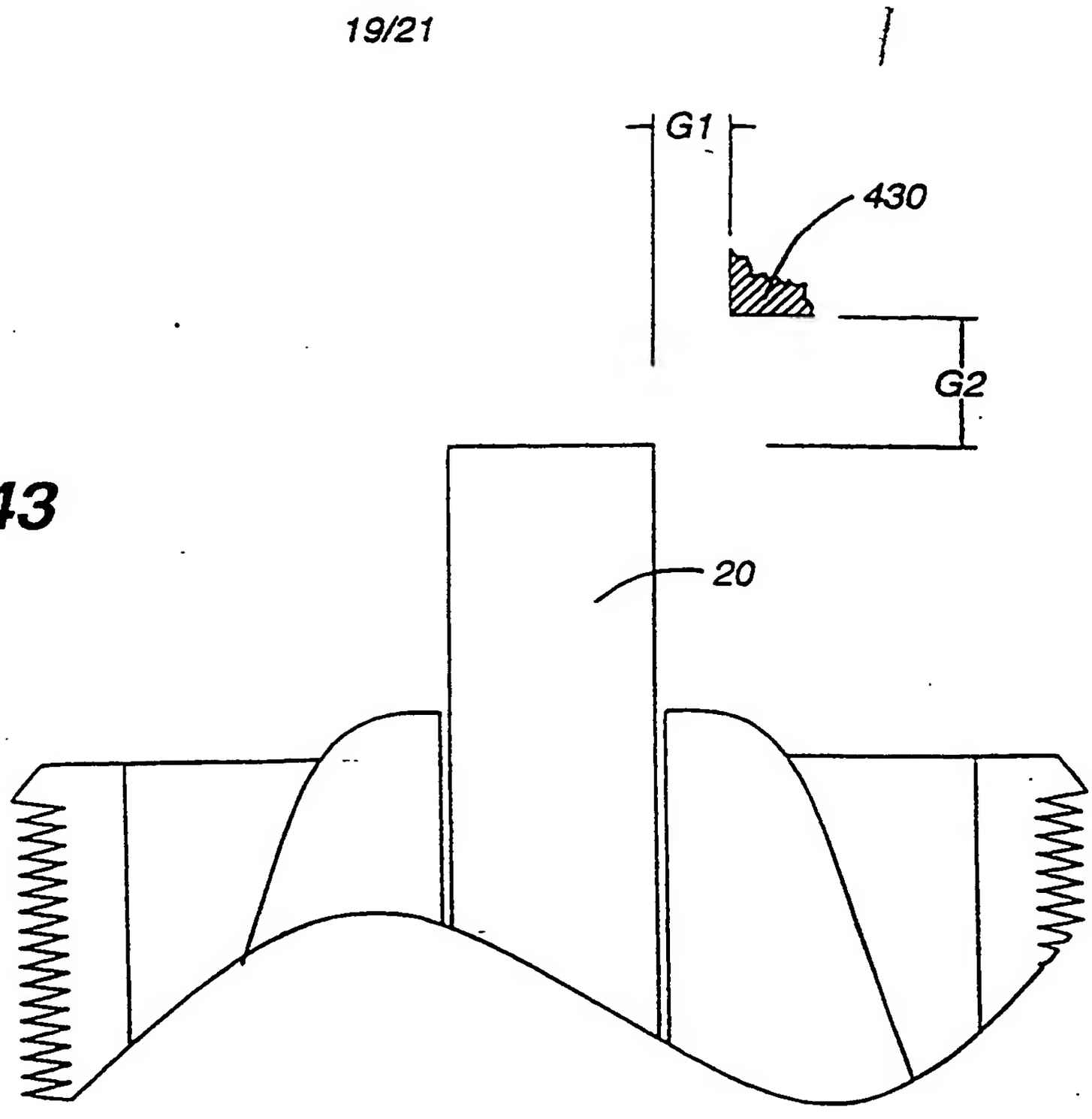


FIG. 43

TANGENTIAL RELATIONSHIP

FIG. 44

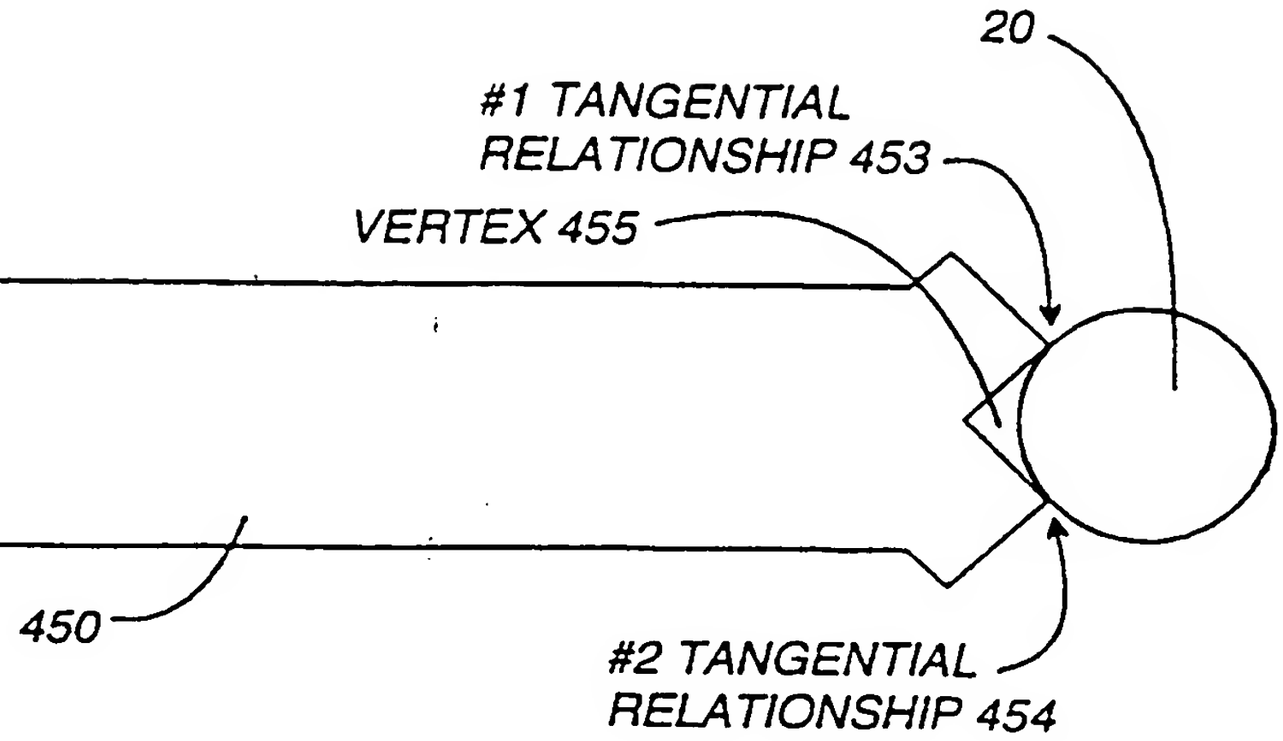


FIG. 45

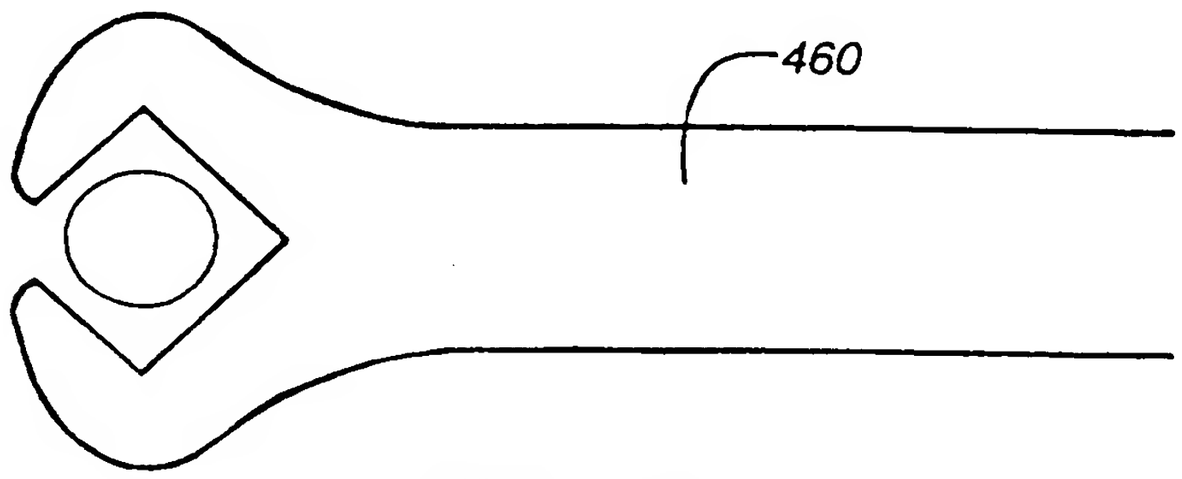


FIG. 46

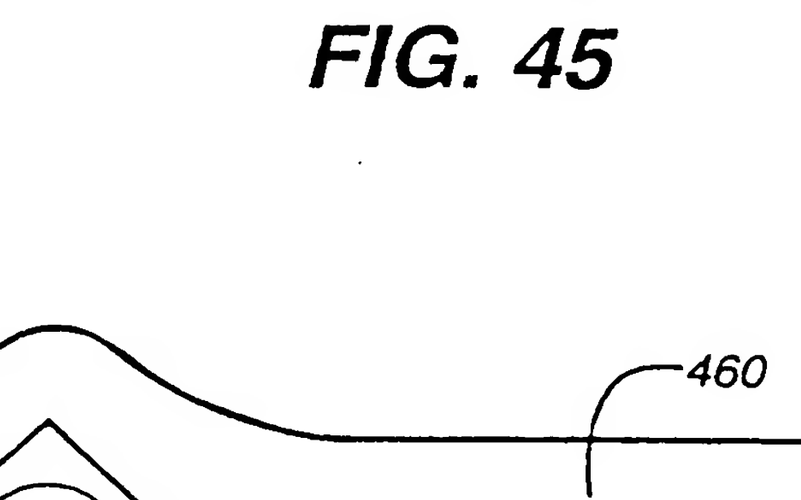


FIG. 47

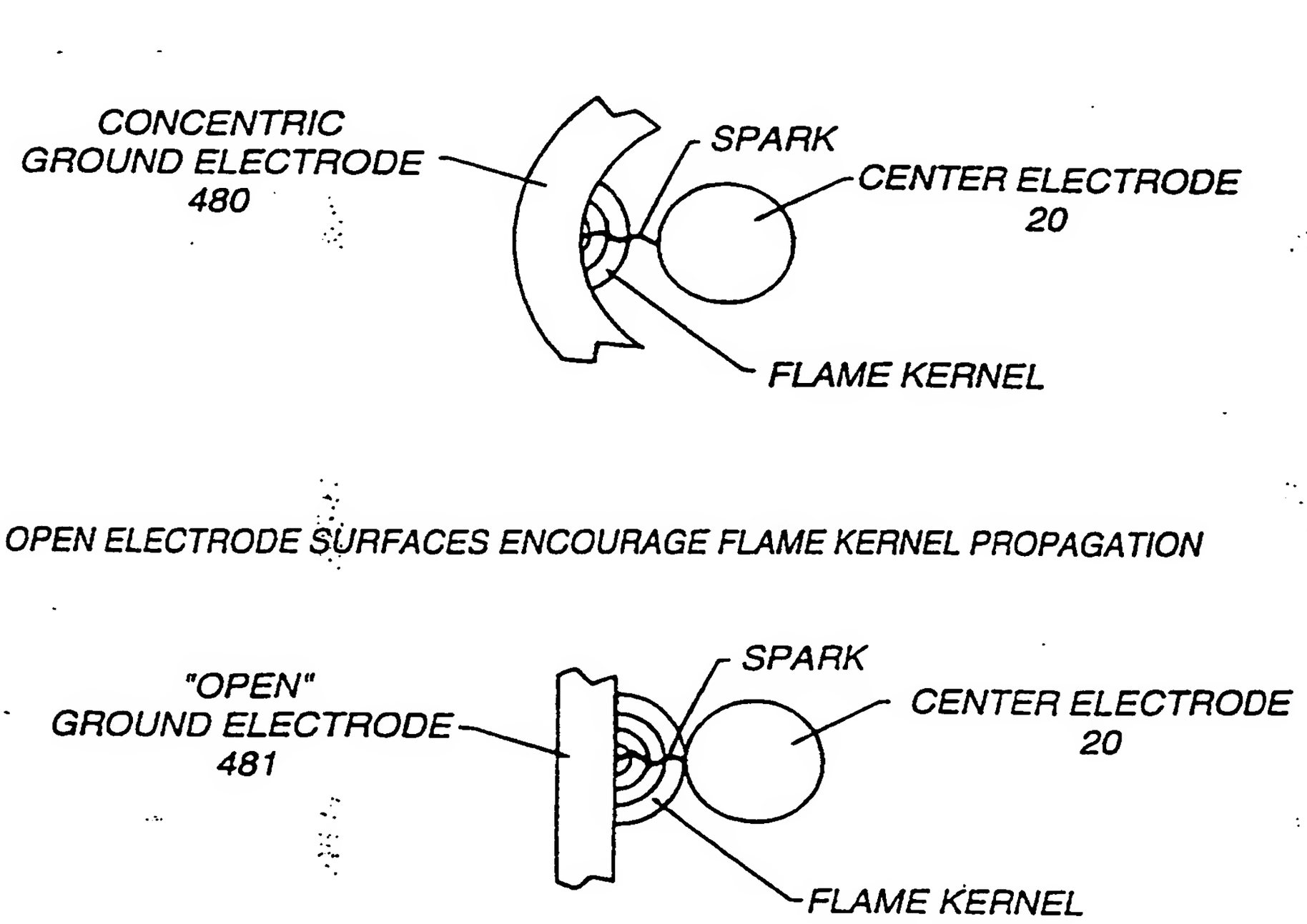


FIG. 48

INTERNATIONAL SEARCH REPORT

Internatio Application No
PCT/US 99/04552

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01T13/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 097, no. 008, 29 August 1997 & JP 09 092434 A (NAKANO TAMOTSU), 4 April 1997 see abstract ---	1,4-8,10
X	DE 94 03 943 U (ZURAN JOHANN DIPL ING ;ZURAN DIETMAR (DE)) 9 June 1994 see page 3, line 1 - line 17; figures 1,4,7-9 ---	1,2,4-17
X	DE 39 35 165 A (HERMSDORF KERAMIK VEB) 25 April 1991 see column 3, line 21 - line 42; figures 2,3 see column 5, line 7 - line 11 --- -/--	1,3-7, 10,16

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
4 June 1999	11/06/1999

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 268 774 A (FORKUM JR MASTON) 19 May 1981 ---	
A	US 5 264 754 A (GIGUERE JACQUES L ET AL) 23 November 1993 -----	

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Internatio application No
PCT/US 99/04552

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 9403943 U	09-06-1994	NONE	
DE 3935165 A	25-04-1991	NONE	
US 4268774 A	19-05-1981	NONE	
US 5264754 A	23-11-1993	CA 2088032 A	25-07-1993